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Engineering News-Record

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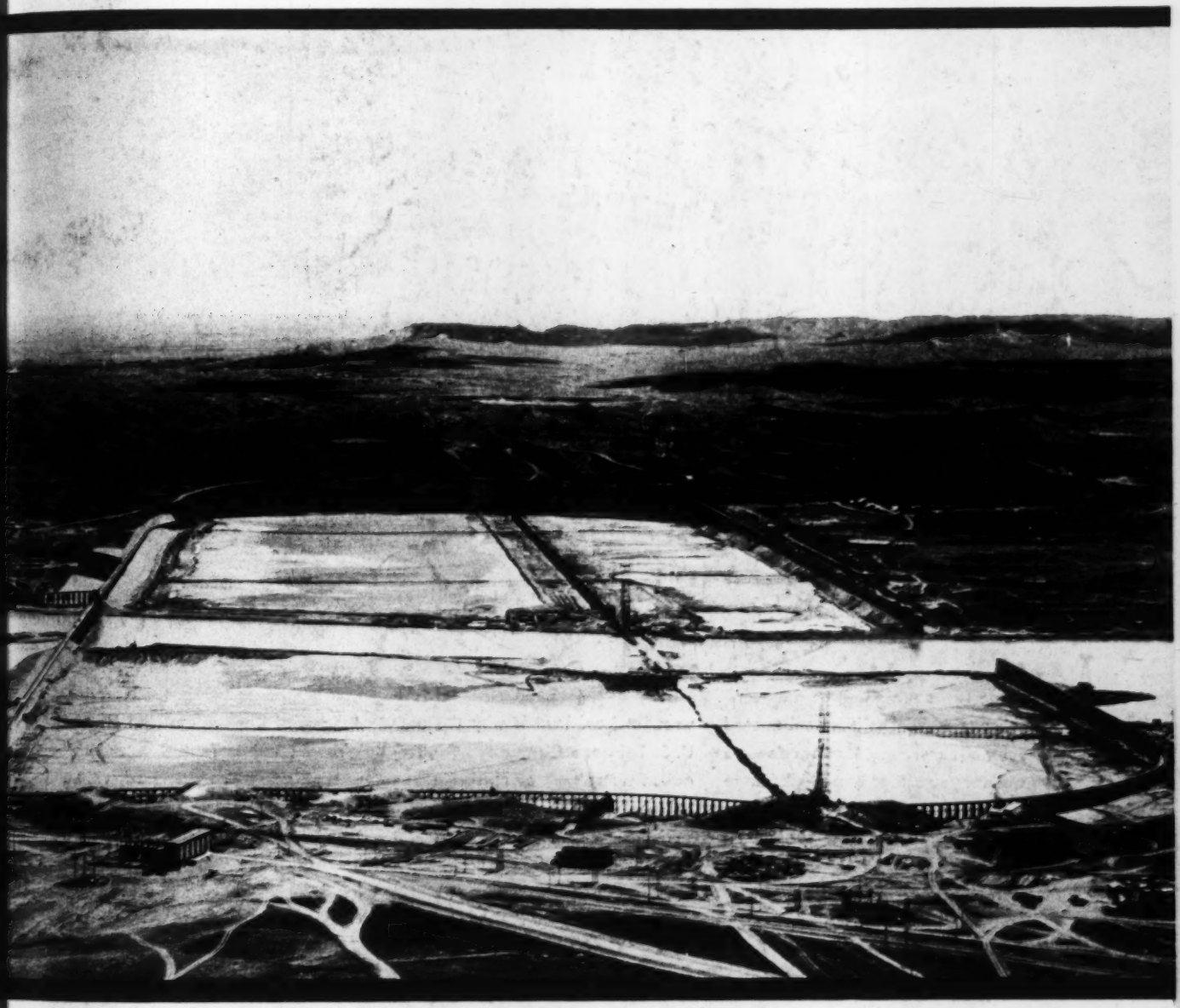
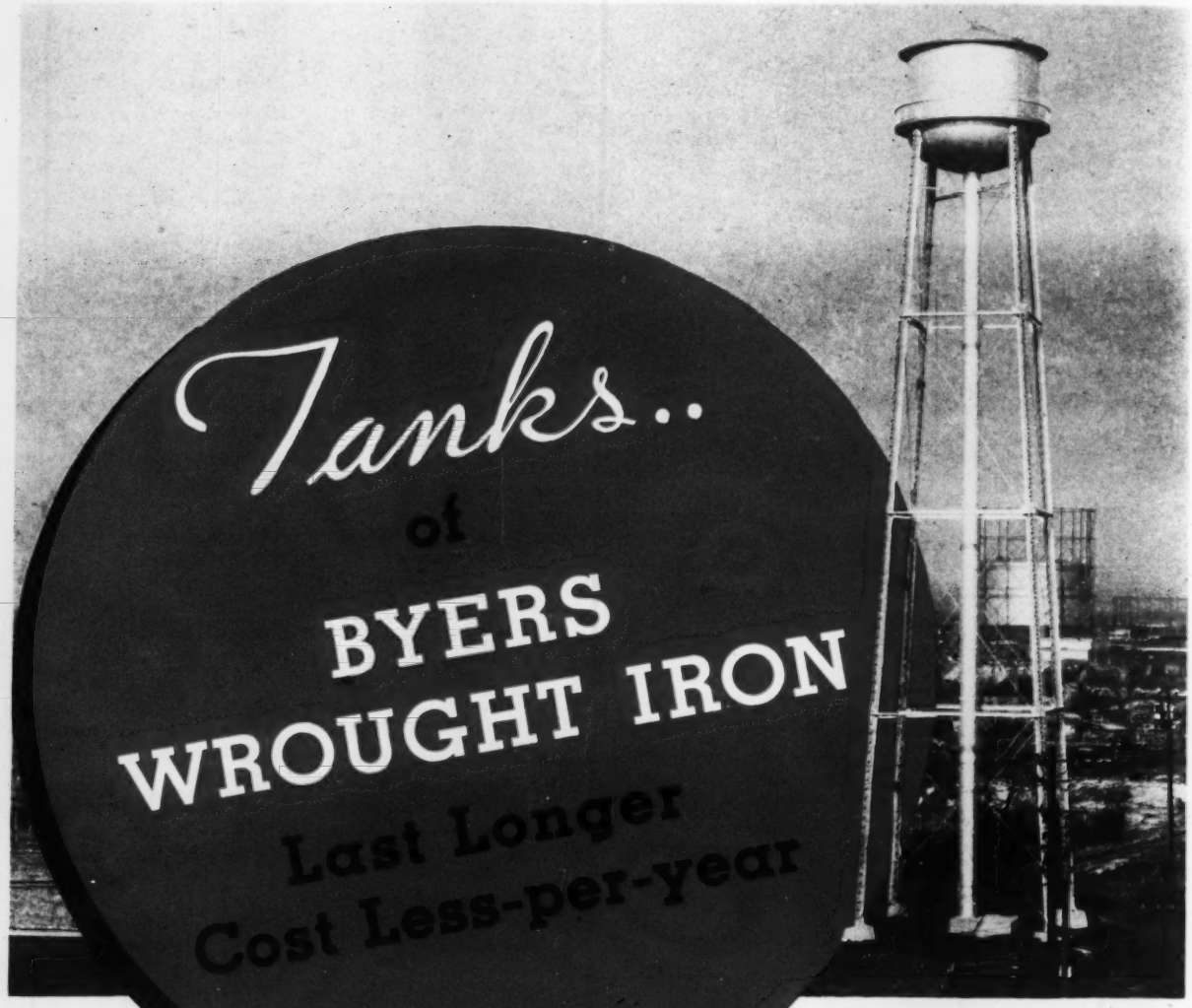


Early stages of placing the 100,000,000 cu.yd. hydraulic fill for Fort Peck Dam

FORT PECK DAM

A group of articles outlining the planning, investigation and construction procedure in building the world's greatest earth dam



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Of the Field, *For* the Field, *By* the Field

THIS page is written en route from New York to Salt Lake City on a journey which is but typical of the constant travel that is required of the editorial staff of this journal.

The editor-in-chief has just returned from a professional convention in New Jersey. One of his associates is in Montana on a trip of several weeks duration that will take him through the Rocky Mountain States; he has but recently completed a two-weeks assignment on a Chicago tunnel job. Another is somewhere on the Pacific Coast, headed for Portland, Seattle, Bonneville, Grand Coulee and intermediate points. A third is in southern California and a fourth has just returned from the flood-swept regions of New York State where he was dispatched on receipt of the first flash. Another, with headquarters in Chicago, soon will be in Texas and the Southwest, while yet another is about to leave New York to cover a story in Detroit. Last year this writer and the editorial staff covered altogether in their business travels more than 60,000 miles.

IN Washington three experienced correspondents write weekly for the paper to sift out and report as to the special significance for engineers and constructors of what is happening there. Throughout the United States and Canada fifty news correspondents and more than one hundred construction news reporters transmit daily their selected items. In the Southeast a special editorial representative maintains close contact with engineers and engineering in that quarter.

At headquarters the office staff constantly is receiving and rewriting telegraph, telephone and mail reports from the field, supplementing spot news with the necessary background and interpretive data, editing contributions and getting out the paper on a weekly schedule that is no less rigid and, during its closing hours, scarcely less pressing than that of a daily newspaper. Indeed, the "Construction Daily," published for those who want their construction news sooner than is possible through a weekly, is a daily newspaper, mailed five nights a week to its subscribers.

A daily newspaper faces certain special problems incident to the breadth of its coverage and the speed of its service; the general magazine must cope with the infinite variety and mobility of public taste and interest: yet neither faces a more exacting journalistic task than does the first-rate technical or industrial weekly.

During the feverish days of the last few years the mere reporting of the news has been of itself no mean task; add to this the need for specialized interpretation and editorial comment that is mindful of the diverse groups that constitute the construction industries, and the job becomes even more exacting. For the readers of this journal are not satisfied with mere home-town gossip or with the superficial and sensational treatment that gets by with the general public. They are technical men with practical interests; they demand, in a journal that assumes to serve them, accuracy and precision as well as speed and judgment: witness the recent uproar —friendly, but none the less admonitory—when a draftsman inadvertently misnamed a river in the lettering of a small map. Moreover, these readers, who know so precisely what is what, are scattered the world over: only a few days ago those of us who happened to be in the office enjoyed a stimulating contact with a reader from New Zealand who, in New York for a few days, was kind enough to pay us a call. But wherever they may be working, these readers want the technical news, not just of their own valleys, but of the rest of the world.

Truly this requires a staff that must know what is going on, see it first-hand so far as may be practicable, interpret it wisely and report it interestingly. To do this it never must earn the reproach levelled at Telemachus that he tarried at home, "news-gathering still from his chair." Your first-rate technical or industrial journal must be of the field, for the field and by the field.

ALL this means that such a journal is a cooperative enterprise. What it may itself accomplish for its field is but the reflection of the interest and the active cooperation of those who carry on the work of that field. And so, this writer would take this opportunity to record his gratitude to those thousands of civil engineers, construction men and manufacturers the world over whose ready cooperation and continued patronage make possible our return service to them. Their information, data, suggestions and inspiration—yes, their reproof and criticism also, are essential to the worthy performance of our job. Whatever *Engineering News-Record* may mean to civil engineering and construction, the field itself has had no small part in its accomplishment.

Willard Chevalier

ENGINEERING NEWS-RECORD

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VOLUME 115 NUMBER 9 COPYRIGHT 1935

Fort Peck Dam

Main Features of Its Current Construction

NEAR the headwaters of the Missouri River, at Fort Peck in northeastern Montana, there is now under construction the greatest of all earth dams. The unprecedented magnitude of the Fort Peck project has required a new approach even to ordinary construction operations and has introduced problems in planning and construction rarely encountered in normal practice.

To grasp these problems, one must first visualize the job—100,000,000 cu.yd. of earth to be placed in a hydraulic-fill dam—a two-mile spillway cut requiring 13,000,000 cu.yd. of excavation—nearly five miles of 32-ft. tunnels driven through treacherous shale rock with 1,000 ft. of 60-ft. shafts for control works. These are major features. Some of the lesser items include such otherwise large operations as construction of 43 miles of railroad, of which 6½ miles is on trestle; building a complete modern town to accommodate a population of 5,000; production of more than 5,000,000 cu.yd. of sand and gravel for concrete and for toe fills; design and construction of four complete dredging units with accessory floating and service plant; and the stripping of 4,000,000 yd. of topsoil from the base of the dam. How was the construction of this vast project planned and organized? How are the widespread construction activities coordinated and how are men, machines and materials marshalled on a scale sufficiently large to insure the orderly conduct of the undertaking? Answers to these questions will be found in the articles presented in this issue, grouped together to record the methods used on the largest construction operation of the present time.

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To help clear the stack gases of cement particles and to save that cement for return to the kilns, huge hoppers like those you see at the left are installed in the plants where Universal and Atlas portland cement is made.

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It is not at all our idea to try to set ourselves up as experts. You who are practicing contractors and engineers certainly know as much theory and considerably more about actual job conditions on concrete work than we do.

But we have accumulated considerable helpful material on cement and concrete in our years of carrying on the business of cement-making—not only theory from the laboratory but also job-practice experience and results learned from men like you in the field. And each year we tackle new problems on some of the many projects where Universal Atlas cements are used, and learn new things thereby.

So *this* is our idea—if the information we have gathered and have on file can be useful to you at any time, we want you to take advantage of it. And there's no charge, of course—it's a service that is as much a part of the manufacture of Universal and Atlas cement as are those dust hoppers in the plants. Try us out!

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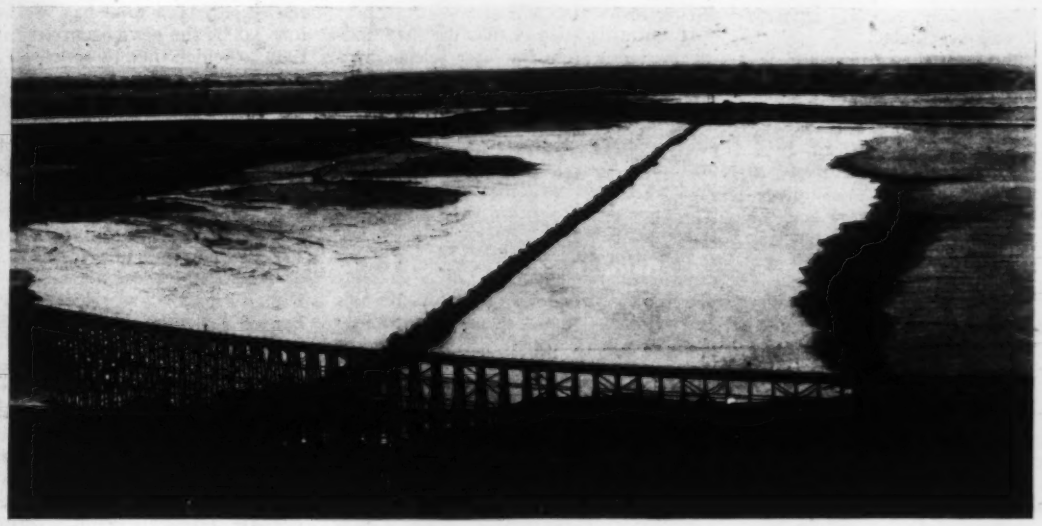
ENGINEERING NEWS-RECORD

August 29, 1935



OVER TWELVE MILLION YARDS of material have been pumped into the broad base of Fort Peck Dam, bringing the wide core pools close to the upper limits of the sheetpile cutoff wall.

Fort Peck Project and Dam

By Thomas B. Larkin
Major, Corps of Engineers,
U. S. District Engineer, Fort Peck, Mont.

THIS ISSUE

ENGINEERING NEWS-RECORD presents in this issue a summary and details of construction progress and procedure on Fort Peck Dam.

The information has been obtained by a field study by one of the editors which has been checked by the engineers in charge, who also have contributed special discussions of planning progress and methods.

Fort Peck Dam is essentially a problem of construction, of how to move and place enormous volumes of earth and rock and concrete. Problems of design, of choice and character of structure, had to be solved and broad questions of economies had to be determined, but primarily engineering judgment has been called upon to decide how to do work instead of what work to do. How the work is being done is told in this issue.

THE FORT PECK PROJECT is unique in the many original engineering problems that it involves and is record-breaking in its proportions. The unprecedented size of the dam, to store 19,500,000 acre-ft. of water, involving 100,000,000 cu.yd. of hydraulically placed earthfill, and the peculiar structure of the basic shale formation through which the diversion tunnels and spillway are being built, are the sources of major engineering problems. Another feature without precedent is the driving of a steel sheetpile cutoff wall the full length of the dam through 140 to 190 ft. of valley-floor covering to shale bedrock.

At present four 28-in. electrically driven suction dredges are pumping material into the base of the dam, an area 2,800x8,000 ft., at the rate of 3,000,000 cu.yd. per month. To date, more than 12,600,000 yd., or more than one-eighth of the required total, have been placed, mostly all in this year's dredging season. Because the diversion tunnels are as yet incomplete, the Missouri River splits the fill into two parts, which adds to engineering and construction difficulties by necessitating sand plugs or levees along the river banks to retain the pumped fill.

Four diversion tunnels, 32 ft. in excavated diameter and totaling 4.79 miles in length, are being driven under the cast abutment. Center pilot headings have been holed through in each of the four bores, and enlargement to full size and installation of steel rib supports and concrete lining are now under way. Rapid disintegration of the shale upon exposure to air complicates the tunnel work.

Far to the east of the dam a spillway two miles long is being excavated, requiring the removal of 13,000,000 cu.yd. of shale and overburden. In nine months two contractors have completed

about three-fourths of this excavation with shovel and truck fleets. Building of a concrete gate structure at the spillway inlet is now under way, and as the main excavation nears completion the lining of a mile-length of the cut and installation of a deep cellular concrete cutoff wall will be started.

The magnitude of the project and the engineering and construction problems involved will become more apparent as one reads the succeeding articles and need not be further emphasized here. Main attention rather will be given to the purposes for which this unprecedented earth dam was planned and the sequence of planning and construction operations as far as they can be recorded up to this time.

Purpose and principal features

Primarily the Fort Peck Dam is being built to improve the Missouri River for navigation from Sioux City, Ia., to St. Louis, Mo. Secondarily, it will have functions of flood control, and it may ultimately serve also as a source of irrigation water.

Studies made during 1928-32 in connection with the preparation of the "308 Reports" of the Chief of Engineers, U. S. Army, indicated that if an 8- to 9-ft. channel was to be maintained on the section of the Missouri indicated, the low-water discharge would have to be augmented. It was determined that a minimum flow of 30,000 sec.-ft. at Yankton, S. D., would be required to assure the channel depth desired, and that this minimum flow could only be secured by creating a large reservoir in which to store floodwaters for release during low-water periods.

It naturally follows that the impounding of floodwaters for later release provides flood-control benefits. Many thousands of acres of arable farm lands below the dam that in the past have been subject to destructive floods will be protected to a large extent. An attendant benefit with that of flood control is the lessening of river-bank erosion.

The operation of the dam for navigation and flood control will also make possible the production of a considerable amount of prime and secondary power, a possible use of which will be to pump water from the reservoir to irrigation projects within reasonable transmission range. About 180,000 acres of irrigable land offer potentialities for development by this method.

Aside from these strictly engineering purposes, the Fort Peck project is being constructed at this time with Public Works Administration and Emergency Relief Administration funds as a measure of unemployment relief. The work has been carefully planned to provide jobs for about the same number of persons continuously rather than have sharp and seasonal fluctuations. How well this has been accomplished is indicated by the fact that since July, 1934, the employment total has not fallen below 5,000; the peak occurred in August, 1934, at which time there were 7,200 persons on the rolls. At present there are over 6,500 employed. Naturally, with the large amount of supplies required this project is also giving much employment not included in the foregoing figures.

Several possible dam locations were considered in connection with the "308 Reports" surveys (*ENR*, Nov. 29, 1934, p. 693). Of these sites that at Fort Peck (Fig. 1) was selected for a number of reasons. Here the valley narrows to a width of about 7,500 ft., widening above to form a large reservoir area, sufficient to store the amount of water required. Also, the site is located in the outcrop belt of the Bearpaw shale, a dense marine formation of the Mesozoic Era. When undisturbed this shale is firm and has reasonable bearing power. With a thickness of about 1,000 ft., and lying in no part of the construction area at a greater depth than 160 ft. below the surface, the shale, while at too great a depth for a masonry or concrete structure, provides a most suitable foundation for an earth dam. In addition, the alluvium in the river

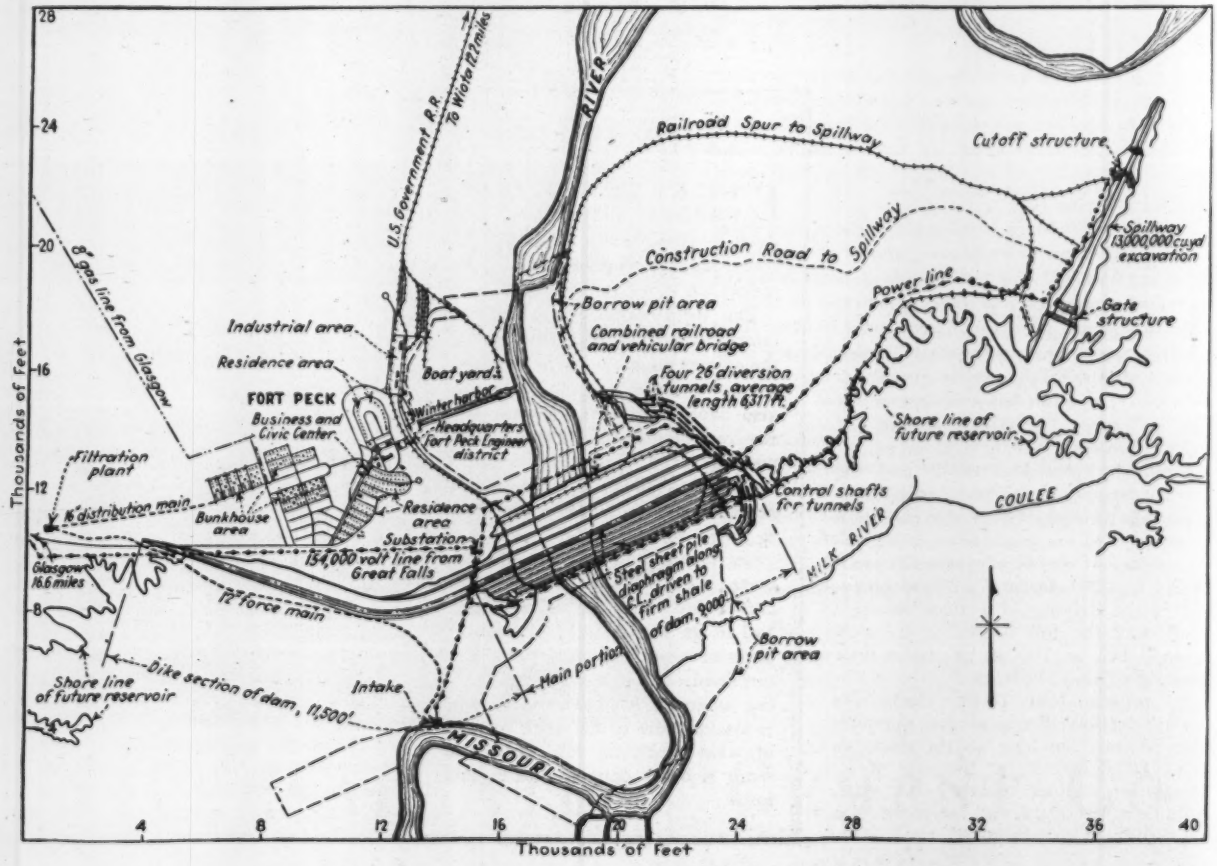


FIG. 1—PROJECT MAP of Fort Peck, showing location of the various structures and distances embraced by the area of operations.

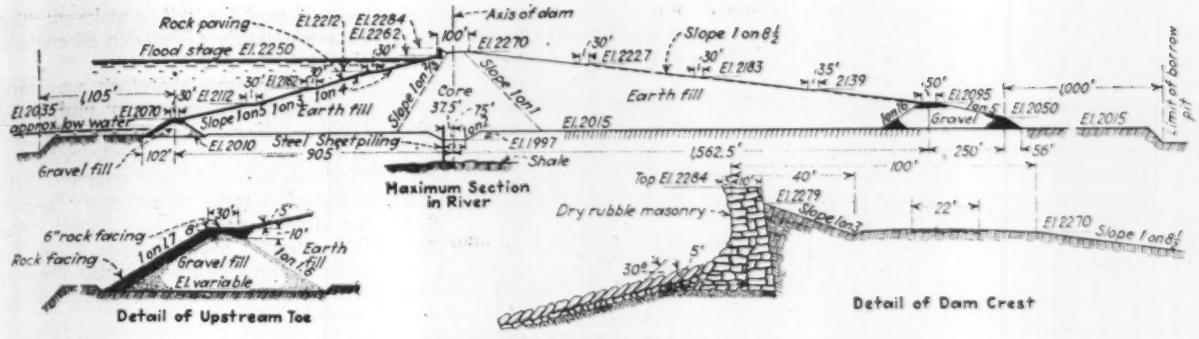


FIG. 2—WORLD'S largest earth dam shown in cross-section. It will be 2,875 ft. wide at the base, 9,000 ft. long at the crest, with a dike extension 11,500 ft. long. The flat slopes account for the 100,000,000 cu.yd. of fill required.

valley was found to be entirely satisfactory for building a dam of this type.

From the section of the dam shown (Fig. 2) it will be noted that, to reduce percolation under the structure, a steel sheetpile cutoff wall extends from bluff to bluff, driven to the underlying firm shale. Prior to placing fill, all objectionable materials such as clays, vegetable matter and deteriorated shale, amounting to over 4,000,000 cu.yd., were removed from the site of the dam. The placing of the earthfill on the base so prepared is being performed by the hydraulic method. In view of the unusual construction hazards, the necessity for rigid control of materials and the required coordination of operations, all work in connection with placing the fill and building the gravel toes is being performed by the government under force account, using owned plant and hired labor.

To provide for a normal flow of the river, four diversion tunnels (Fig. 3), with a capacity at full head of 84,000 sec.-ft., are under construction through the bluff on the east abutment. On this side of the valley the shale comes close to the surface, thus allowing the tunnels to lie entirely in firm material. To pass extreme floodflows, a spillway (Fig. 4) with a maximum capacity of 254,000 sec.-ft. is included in the project. This structure is located in the shale bluffs 3 miles east of the east abutment of the dam.

Order of operations

Considerable timber exists on the bottomland of the Missouri in the vicinity of the dam. Clearing of the site was, therefore, the first operation, and this began on Oct. 23, 1933, nine days after the project was approved. Shortly thereafter a temporary camp was constructed. To provide immediate employment during the first winter and spring, supply contracts were promptly let for collecting and piling 500,000 cu. yd. of glacial boulders, later to be used in the toes of the dam. These were obtained in the area near Saco and Malta, Mont., about 70 miles from Fort Peck.

When operations were begun, the only road to the dam site was narrow and unimproved and practically impassable in wet weather. A great portion of the timber for the dredging units was transported over this road during the winter of 1933-34. Access for motor vehicles was vital, so government forces were utilized to keep the road open, gravel being spread where necessary, grading being done and snow removed. In the spring of 1934 the state of Montana started on the construction of a new hard-surfaced highway from Glasgow to the dam. This was completed and opened to traffic on Aug. 13 last year.

Railroad construction

The construction of a railroad to the dam site was of the greatest importance and of immediate necessity for work to proceed without delay and undue expense. Prompt building of the railroad would also provide additional immediate employment as well as make possible the earlier employment of many men on other phases of the project. After advertisement had failed to secure any suitable bids, and in view of the need for haste along with the hazards of winter construction, it was decided to perform the work by hired labor. Work on the 12.2-mile line beginning at Wiota, Mont., on the main line of the Great Northern Ry., was started on Dec. 18, 1933, with June 4, 1934, as the scheduled completion date.

The railroad line crosses the Milk River, and a contract was let for the construction of a bridge over this stream. To realize maximum progress on other parts of the project during the 1934 construction season, it became apparent that earlier completion of the railroad was highly desirable. Intensely cold weather during the latter part of December and early January was followed by an unseasonable thaw. Many plant and supply difficulties were encountered. In spite of these obstacles to progress, the road was finished and officially opened on April 16, 1934. Even before that date it was sufficiently completed to allow the movement of many carloads of material to the dam site.

It is estimated that for the entire project a total of 12,000,000 tons of material will move over the road, requiring 300,000 cars, or 6,000 trains of 50 cars. To date, about 4,500,000 tons have been received. Some of the major items that have been or will be handled are: sand, gravel, cement and steel for the diversion tunnels and the spillway; timber and steel for the Missouri River Bridge; lumber and building supplies for the town; machinery and lumber for the dredging plant; and rock, gravel and steel sheetpiling for the dam itself.

Dredging Equipment

Dredging plans called for the commencement of full-scale pumping in the spring of 1935 and for closure of the river section in 1937. To insure this schedule, it was essential that a prompt start be made on construction of the diversion tunnels. But, if proper progress were to be secured on the tunnels, railroad and vehicle passage over the river was a prime necessity at the earliest possible date. Accordingly, a contract was let in February, 1934, for a bridge across the Missouri River at the downstream toe of the dam. This structure was sufficiently completed to allow the first train to cross on Oct. 1, 1934. Railway trestles as extensions to this bridge were necessary, primarily to provide a means of dumping gravel and rock along the upstream toe of the dam, and secondarily, on the right bank, to provide rail transportation to the upstream tunnel portals. These trestles were built under contract during the summer and fall of 1934.

With the adopted plan of operations calling for full-scale dredging to begin in the spring of 1935, and for doing this work by force account, it was obvious that immediate steps had to be taken for the construction of the four wooden-hull dredges and their attendant plant. Accordingly, on Jan. 10, 1934, the first work was done at the boatyard in Fort Peck. As there are no boatyards in Montana, the problem of finding good ship carpenters and calkers was presented. Seventeen men made up the starting crew, with hand tools as the only equipment. In a short time many more men were added and modern power tools were supplied. One complete dredging unit was started so that it might be completed in sufficient time to go into operation in the fall of 1934. On the night of Oct. 11, ten months after her keel was laid, dredge unit *A*

(now named "Gallatin") began pumping pay dirt for the big dam. The other units of the dredging fleet were launched at intervals, and all were ready for action in ample time for the dredging season of 1935.

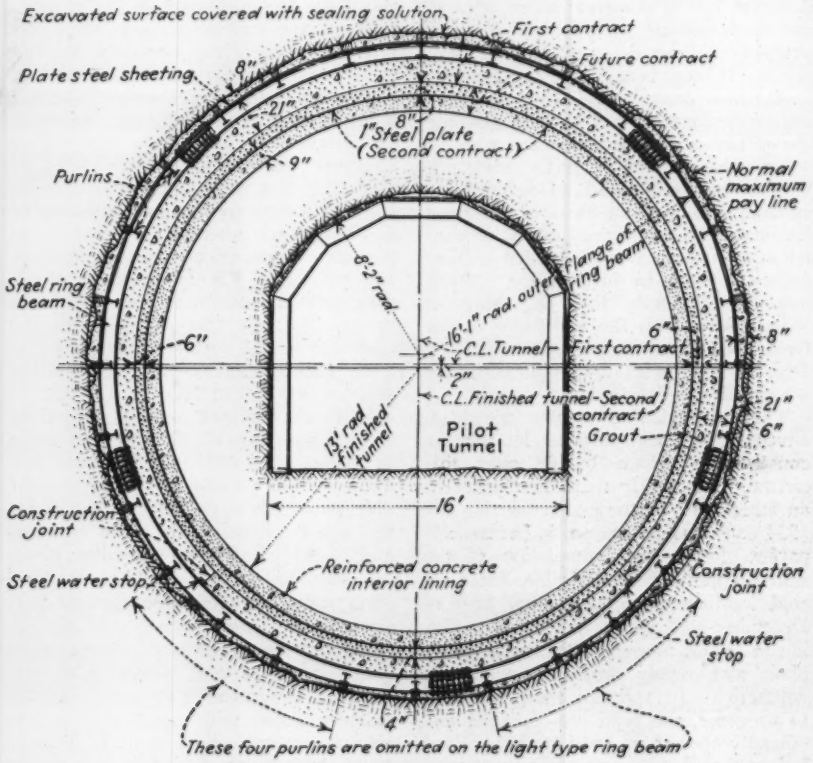
Another problem requiring prompt study and decision was that of the supply of energy necessary to pump the tremendous yardage of the dam into place. After a thorough investigation of all possible methods, it was determined that the most economical and satisfactory power supply could be obtained from the existing hydro-electric plant of the Montana Power Co. at Great Falls, Mont. This necessitated the decision to construct a 288-mile, 154,000-volt power line with its attendant substations and necessary distribution system at Fort Peck. Contracts were let promptly for all portions of the installation, and the first power was delivered over the line on Oct. 1, 1934.

Lack of living facilities at the dam site, coupled with the rigorous climate, necessitated building a complete construction camp together with all needed facilities for the housing of the large number of employees required during the construction period. Designs were rapidly prepared and contracts let, to provide for the temporary town of Fort Peck at the dam site. These designs were based upon an immediate population of 4,600 workmen. Construction on the town began in the middle of April, 1934, and practically all buildings were ready for occupancy by Oct. 1, 1934. With paved streets, natural gas for heat, a modern water-filtration plant, an excellent sewer system, ample recreational facilities, including a motion picture theater and a large recreation hall, a well-equipped hospital, the town of Fort Peck provides a most comfortable place in which to live.

Prior to the final design and location of all the main features of the project, very extensive borings and subsurface explorations were made. In all, over 17½ miles of borings were made, many holes being more than 160 ft. deep. An experimental tunnel was driven into the bluffs on the right (east) abutment, to secure data on the tunneling problems that would have to be solved. Thousands of samples were taken in the borrowpit areas, to determine the type of material available and to make sure that an ample supply of suitable fill could be obtained.

A soil-testing laboratory was early established with temporary quarters in Glasgow, Mont. Later, when the town of Fort Peck was completed, the laboratory was moved to new quarters there, equipped to make all necessary tests on the dredge fill as it is placed. The laboratory is also equipped to test all other materials entering into the construction of the project, such as concrete, steel and rock.

FIG. 3—STEEL AND CONCRETE LINING of the diversion tunnels. Present structural lining consists of steel rib bents and encasing concrete; future work will require a steel-plate pipe set in an envelope of grout and protected by an inner concrete lining.



Details of Steel Rib Supports			
	Light Type	Int. Type	Heavy Type
Ring Beams	7"-12 lb. I @ 5' c. to c.	8"-21 lb. I @ 5' c. to c.	10"-29 lb. I @ 3½' c. to c.
Purlins	5"-10 lb. I	6"-14.75 lb. I	8"-17 lb. I
Sheeting	18 ga. x 20"	18 ga. x 20"	18 ga. x 12"

First pumped fill

Fill poured into the dam area for the first time on Oct. 11, 1934, when the initial dredging unit went into operation. This preliminary work was performed for three reasons: (1) to provide a channel of sufficient depth in front of the boatyard so that the remaining hulls could be launched; (2) to excavate a winter harbor where all of the plant could be protected during the winter; and (3) to ascertain what, if any, alterations might be necessary in the plant and to apply the experience thus gained to the construction of the other three units. About 900,000 cu.yd. of fill were placed before weather conditions stopped operation on Dec. 22. Full-scale dredging operations with all units began on April 14, 1935, and in four months from that date 12,600,000 cu.yd. of fill had been placed. Unless an early winter occurs, it appears that the season's schedule of 24,000,000 cu.yd. will be attained without difficulty. Work has begun on the enlargement and concreting of the diversion tunnels. It is hoped to have them completed by mid-summer of 1937, at which time dredging of fill will begin for the closure section of the dam. Work on the spillway is well up to schedule. At this time no obstacles are seen which will prevent the completion of the project in 1939 as planned.

Directing personnel

The planning and design of all features of the project have been performed in the Missouri River Division offices at Kansas City, with Col. R. C. Moore, Corps of Engineers, as division engineer. As contracts are awarded, the responsibility for the construction is placed on the Fort Peck District, with the writer as district engineer.

The following officers of the Corps of Engineers are principal assistants to the district engineer, with duties as indicated: Major Clark Kittrell, in charge of operations; Capt. C. N. Iry, electrical power; Capt. A. W. Pence, tunnels; Capt. D. A. D. Ogden, construction of dam; Capt. C. H. Chorpening, steel sheetpiling cutoff wall; Capt. J. B. Hughes, executive assistant in charge of administration; Capt. J. R. Hardin, spillway; and Lt. E. G. Plank, land acquisition and town management.

Fort Peck Project Structures

Dam embankments, outlet and spillway are structurally notable and involve movements of earth and rock far exceeding any in previous dam work

AS INDICATED in the previous article, the permanent structures at Fort Peck, excluding the railway, power lines and certain buildings that will remain for future operation and maintenance, are: (1) the main dam and its flanking dike that will hold back the waters of the Missouri River; (2) the four tunnels that will divert the river around the dam during construction and afterward provide a controlled outlet for the reservoir; and (3) the open-channel spillway, with its control structure that will pass downstream the floodflow of the reservoir and keep its level safely below the crest of the dam. This description is confined to the dam, the tunnels and the spillway.

Main dam and dike

With its 100,000,000 cu.yd. of material, Fort Peck Dam will be by far the largest earth dam in the world and by the same token the largest hydraulic-fill dam, exceeding Gatun Dam in Panama (which now is the largest) by nearly five times. The reservoir created by this 242-ft.-high dam will have a capacity of 19,500,000 acre-ft., two-thirds the capacity of Boulder Dam Reservoir, and will extend up the Missouri River a distance of 187 miles, forming a lake with a surface area of 245,000 acres and a shore line 1,600 miles long.

While the cross-section of the dam has been changed several times since the inception of the project, the latest planned section (Fig. 2) is now considered final, with possible changes in the upstream stone paving and certain crest details. This plan calls for a dam with a crest length of 9,000 ft., rising 242 ft. in maximum height above the existing river bed, with a crest width of 100 ft., including a 22-ft. concrete highway. The maximum width between center lines of toes in the existing river channel will be 2,875 ft. Extending westward from the main dam will be a dike section 11,500 ft. long.

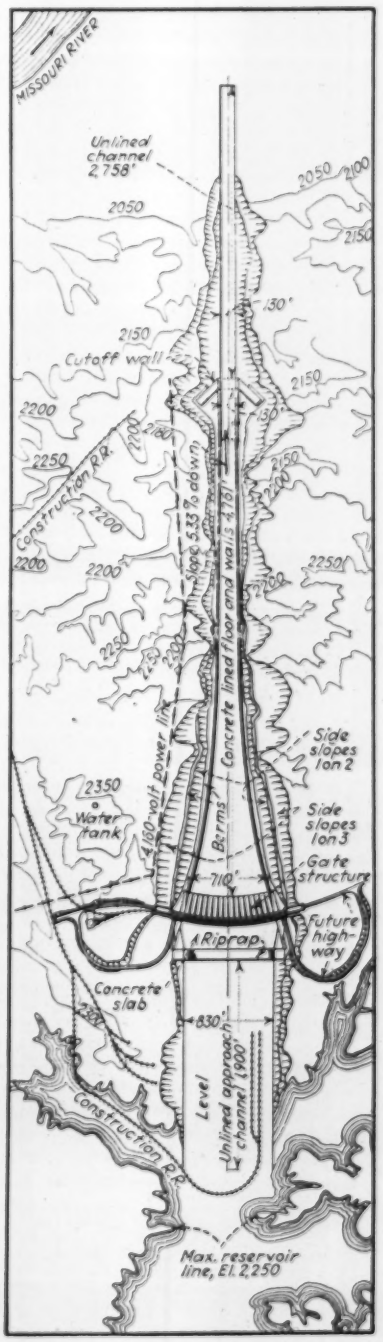
Both upstream and downstream toes of the dam are gravel fills of ¼-in. to 6-in. stone. The upstream toe has a maximum width of 213 ft., and a maximum height of 60 ft., with crest 30 ft. wide; it will be blanketed on the upstream face with fieldstone riprap. The downstream toe, 459 ft. in maximum width, has a crest width of 50 ft. and a maximum height of 80 ft.; no riprap will be placed on this fill.

The upstream face of the dam will have four 30-ft. berms, including that of the toe fill. Above the first berm the slope will be 1 on 5; between the second and fourth berms the face steepens to a slope of 1 on 3.4, flattening out to 1 on 4 above the fourth berm. On the downstream side the face slope is much flatter, averaging 1 on 8½, with one 50-ft. berm at the toe fill, and one 35-ft. and two 30-ft. berms on the earth embankment. This flat downstream slope is necessary to keep the seepage plane within the embankment. To prevent seepage through the valley floor under the dam, a cutoff wall of steel sheetpiles driven down into firm shale is provided along a line 37½ ft. upstream from the axis of the dam.

The waterstop of the dam consists of a trapezoidal central core of fine material deposited in a still pool. This core has unusually steep side slopes—1 on ¾ upstream and 1 on 1 downstream. It is composed of fine silts and clays of an effective size smaller than 0.0054 mm.

PIPE LINES ON TEMPORARY TRESTLES across the dam were used in the early stages of hydraulic filling to build up the downstream beaches. Foundation piling for the waste-weir construction can be seen at the upper left.

FIG. 4—TWO-MILE spillway cut of 13,000,000 cu.yd. and gate structure that will handle the floodflow of the 245,000-acre reservoir.



The core embeds the top 20 ft. of the sheetpile cutoff. In volume, the core is about 20 per cent of the fill.

In brief, the dam consists of the core held in place by embankments of sand, in turn supported at the toes by the gravel and rock fills. The dam requires 100,000,000 cu.yd. of hydraulic fill, 4,000,000 cu.yd. of gravel toe fill, and 1,600,000 cu.yd. of rock (both quarry rock and glacial boulders) for facing the upstream slope. The principal elevations are: deepest part of trench, El. 1997; river bottom, El. 2015; top of upstream toe fill, El. 2070; top of downstream toe fill, El. 2095; crest of dam (roadway), El. 2270; top of parapet wall, El. 2284; flood stage of reservoir, El. 2250; freeboard, 34 ft.

The dike extension of the dam for 11,500 ft. along the western ridge of the reservoir is as yet undetermined in section, volume or method of construction. At present full-size test sections of dike are being built, and laboratory models are being prepared to determine size and shape of fill prism and plane of saturation as described on p. 287. Both hydraulic-fill and rolled-fill embankment are under consideration.

Diversion tunnels

Four diversion tunnels will carry the river flow during the final closure of the channel and afterwards will form controlled outlets for the huge reservoir. The essential elements of tunnel structure are given by the accompanying cross-section (Fig. 3). As there shown, the finished diameter of the four tunnels will be 26 ft., and the diameter of rock excavation is 32 ft. The respective lengths are 5,379, 6,006, 6,629 and 7,254 ft., or a total of 25,268 ft., a little over 4.79 miles.

The capacity of the four tunnels under full-reservoir conditions at El. 2250 ft. is 84,000 sec.-ft. The average river discharge is 8,000 sec.-ft., and the discharge in the maximum flood of record (1908) was 154,000 sec.-ft. Thus the 254,000-sec.-ft. spillway will have to go into action when about half the record flood has been reached, but combined the tunnels and spillway will carry more than twice the record flood. An additional safety factor is that flood peaks will be flattened by the use of the top 8 ft. of the reservoir for flood-control storage.

About 2,350 ft. from the tunnel inlets, main control shafts 60 ft. in diameter and emergency gate shafts 16x34 ft. in plan, sunk about 250 ft. from the top of the bluff, intercept the four tunnels near the axis of the dam. Each control shaft will be braced with steel and then lined with 5 ft. of heavily reinforced concrete containing a steel shell $\frac{5}{8}$ to $1\frac{1}{8}$ in. thick. A concrete chimney, with ring gates, inside the main control shaft will control the flow of water after the dam has been completed. Gates of the Stoney type will be installed in emergency shaft chambers, located 72 ft. upstream from the control chambers. The walls of all shafts are heavily reinforced, to take the full load of the surrounding shale.

Intake and outlet structures of the tunnels are heavy concrete; together they require about 197,000 cu.yd., mostly in heavy headwalls to hold the cut face of the bluff.

Spillway structures

Located in a natural flowageway $3\frac{1}{2}$ miles east of the dam, the spillway (Fig. 4) involves: a cut 9,700 ft. long, requiring 13,000,000 cu.yd. of excavation; a control-gate structure 820 ft. long containing sixteen 40x25-ft. Stoney gates; 259,000 cu.yd. of concrete channel lining, with 130,500 ft. of tile underdrains; and a cutoff wall at the lower end of the lined channel section consisting of a series of reinforced-concrete cells sunk a maximum of 130 ft. into the shale.

In designing the spillway, estimates were made from existing records of the maximum possible runoff from a combination of maximum snowfall and a period of unseasonably high temperatures inducing excessive snow melting, all coming on a full reservoir. The maximum recorded flow of the Missouri River in this vicinity was 1[illegible],000 sec.-ft., in June, 1908. At a pool elevation of 2253.5, the spillway will discharge 255,000 sec.-ft. (surcharge head $3\frac{1}{2}$ ft.). This will safely pass the maximum flood of record independently of the discharge capacity of the four tunnels.

The approach section of the spillway channel as illustrated (Fig. 4) is wide and on a level grade, but upon leaving the gates the channel descends on a grade averaging 5.33 per cent and narrows down to 130 ft. in bottom width. At the gates the spillway flow will enter the channel at a velocity of 24 ft. per sec.; at the discharge end the velocity will be 96 ft. per sec., or about 65 m.p.h.

Fort Peck Land Buying Based on Aerial Maps

AERIAL photographs of the reservoir area of the Fort Peck project are used in appraising and acquiring the land. Triangulation points were flagged prior to making the flights by crosses of 6-ft. squares covered with lime. Section corners are located and identified on each picture, in the field, and individual property lines are then plotted directly on the photographs. The pictures are then used in the field for making the appraisals.

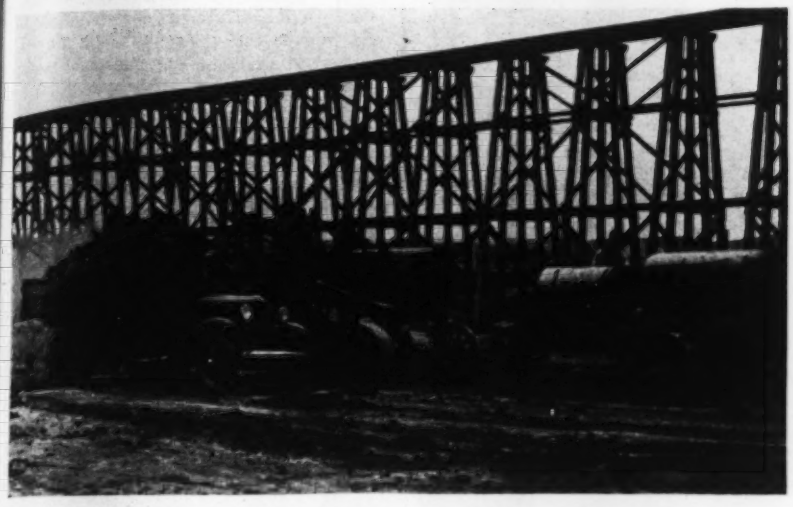
About 275,000 acres of land will be required for the dam site, the town of Fort Peck and the area required for the reservoir, and about 150,000 acres of this land are owned privately, 20,000 acres are owned by the state of Montana, and the rest is public domain land. Representatives of the United States Department of Agriculture examine and appraise all privately and state-owned land and submit a report on each parcel of land. This appraisal report serves as a guide for purchasing the land areas necessary.

There is a very wide variation in the type, grade and quality of land in the area. The various characteristics, together with outlines of fields, soil boundaries and notes on vegetation, topography and other elements having a bearing on the appraised value of a tract are recorded on the aerial photograph. The unit value of each sub-parcel of land in the tract and all physical improvements such as buildings, fences and wells are then appraised by the field appraisal party. The acreage in each sub-parcel is then determined, and the total appraised value, together with a report, is submitted to the Land Acquisition Section, to assist in the purchase of the land.

Lieut. E. G. Plank is in direct charge of land acquisition, and H. A. Ward, of the Department of Agriculture, is in charge of appraisals.

MUD-CHINKED, sod-roofed log cabins, dating back to pioneer days, are the typical homes of the upper Missouri River Valley to be drowned out by the Fort Peck Reservoir.

CONSTRUCTION OF MAIN DAM



A MOSQUITO FLEET of light fast trucks, loaded by nine elevating graders and six shovels and draglines, moved a million yards a month in stripping the Fort Peck Dam site.

Exploring Foundations and Pits

To obtain complete soil profiles and bedrock data under the dam, diversion tunnels and spillway, a drilling program aggregating 87,300 ft., or 17½ miles, of bore holes was carried out—Thorough laboratory studies of the soil made

By T. A. Middlebrooks
Associate Engineer in Charge of Field Investigations, Fort Peck Dam

THIS DISCUSSION divides logically into two parts: (1) underground exploration to determine foundation conditions and character of materials; and (2) study of materials for the hydraulic fill, and particularly control of the core material.

I—Soil Tests and Analysis

IN MAKING the "308" survey for a possible dam at Fort Peck a sufficient number of borings and subsurface explorations had been included to determine the suitability of the foundation to carry a dam and the availability of satisfactory material at the site to construct a dam by hydraulic methods. Obviously this was but a reconnaissance study that had to be greatly extended when actual construction was decided on. Immediately following the approval of the project, therefore, an extensive surface and subsurface soil survey was begun. Surveys were made of the surface strata exposed at various parts of the site. After this, wash borings were made through the overburden, followed by core drilling several hundred feet into the underlying rock foundation.

Bedrock at the Fort Peck Dam consists of the so-called Bearpaw shale, a firm shale interspersed with thin layers of Bentonite clay. The east abutment is composed for the most part of shale, covered with a few scattered remnants of glacial drift. The flood plain of the river valley has been built up over a long period of time by river deposits of gravel, sand, silt and clay to a maximum depth of 160 ft. This alluvium lies on the Bearpaw shale, which is estimated to be approximately 1,000 ft. thick in this region.

Outcroppings of the Bearpaw shale extend about 100 miles east from the site. This rock, of distinctly marine origin, weighs about 140 lb. per cu.ft.; it is extremely dense and because of its density and high clay content is quite impervious. Jointing planes and small fractures or displacements are numerous throughout the formation, but the borings and test pits show no indication of any continuous fracture zone which would permit appreciable seepage through the rock foundation of the dam and its abutments. The formation next beneath the Bearpaw shale is Judith River sandstone.

The west abutment of the dam is composed of three distinct formations. From the surface to a depth of 125 to 170 ft. there lies a deposit of glacial till made up of a uniform gradation of gravel, sand, silt and clay. The mixture is fairly dense, weighing about 130 lb. per cu.ft. Below this lies a stratum of preglacial alluvial deposit composed of sand, silt and clay, in turn resting on the Bearpaw shale, which outcrops at the abutment just above the present valley floor.

Subsurface investigations were systematized to reveal thoroughly the foundation conditions at the dam site, the nature of the materials in the proposed borrowpits for dredging, rock conditions at the tunnels, and the character of the various proposed locations for the spillway.

Dam foundation and abutments

The site of the main portion of the dam was laid out for boring every 300 ft. along the axis: three rows of holes upstream of the axis at 1,000-ft. spacing, and six rows downstream of the axis at the same spacing. Fig. 5 is a layout of the foundation and borrowpit boreholes.

Drive samples were taken every 5 ft. or wherever there was an indication of change in the soil formation. In dry holes good samples of fine sand, silt or clay were obtained with a sampler made of 3-in. pipe, 2 ft. long, having a check valve and a drill-rod connection at the top. In medium sand, coarse sand and fine gravel an inverted clamshell drive sampler was used effectively; in some cases it was necessary to use an ordinary sand bailer, but this was found unreliable in giving a truly representative sample.

Fig. 6 shows a typical profile of the strata composing the foundation of the dam after the surface gumbo had been stripped and carried away. Fine-grained sand is the predominating material, interspersed with layers of coarse sand, gravel and clay. The clay is very stiff and has a low moisture content, indicating that it was consolidated by a much greater load than that of the present overburden.

Numerous connecting layers of coarse sand and gravel, the clay bed extending down the center portion of the valley to a point below the dam, and outcroppings of sand near both abutments indicated the advisability of some measures to reduce seepage and prevent piping through the foundation. The connecting layers of sand and gravel might permit an appreciable volume of seepage, and the stiff clay would force it to percolate up through the sand below the abutments. Therefore, it was decided that a sheet-pile cutoff wall driven into the shale

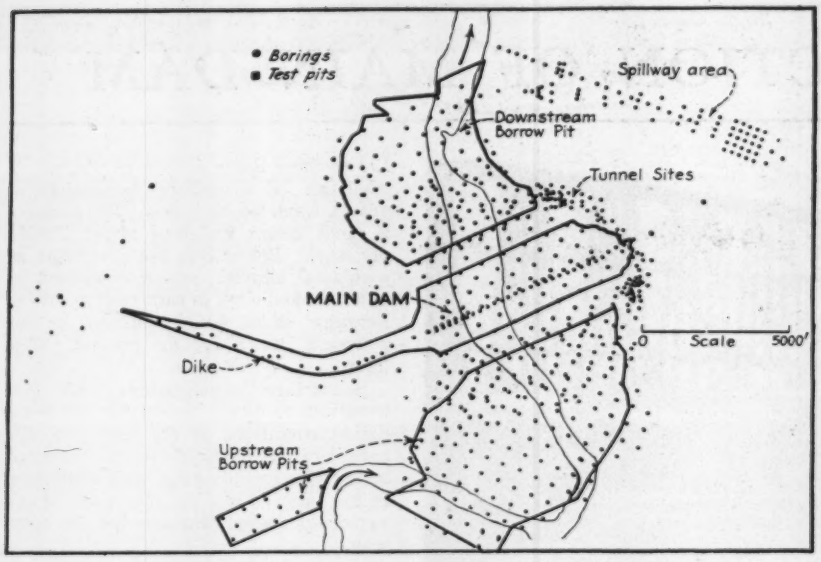


FIG. 5—BORINGS AGGREGATING 17½ MILES of holes for foundation exploration and for an analysis of hydraulic-fill materials cover main dam and dike, borrowpits, tunnel location and spillway area.

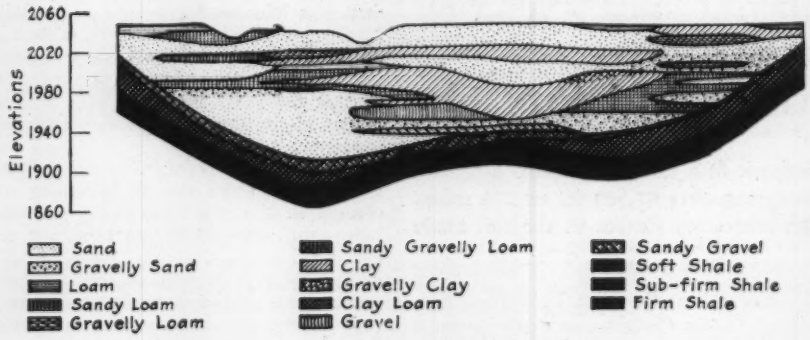


FIG. 6—TYPICAL SOIL PROFILE of main dam foundations after the surface gumbo had been removed.

foundation was desirable to give the desired factor of safety against piping.

Borings and test pits on the right abutment show that the disintegrated and weathered shale extends to a depth of approximately 30 ft. below the surface. This 30 ft. of shale is broken up and disintegrated to such an extent that an undue amount of seepage might occur below the puddle core. In order to prevent this seepage, two plans were considered: (1) cutting a core trench into firm shale, and (2) driving a sheetpile cutoff wall. Cutting a core trench 30 ft. deep through the weathered and disintegrated shale from the base of the abutment to the top and keeping the exposed firm shale from further weathering until the core could be placed upon it presented a very difficult problem. This shale disintegrates rapidly when exposed to the air; therefore, it would have been necessary for this additional weathered material to be stripped just ahead of the core fill. It was decided that the sheetpile cutoff wall, when driven into firm shale, would satisfactorily reduce the seepage and could be placed at a minimum cost with less danger of unforeseen difficulties delaying the construction of the dam.

A detailed study of the left abutment shows that there is a possible danger of excess seepage occurring through the sand strata underneath the glacial till; therefore, the cutoff wall is extended far enough along the center line to increase the path of percolation sufficiently to obtain the desired factor of safety against piping.

Stripping

Foundation borings showed that practically the entire base of the dam was covered with a clay deposit that was underlain by a pervious and stable sand. On the east bank the clay was derived from the Bearpaw shale bluffs and was composed of the finer particles of this deposit. The west bank clay was derived in most part from the glacial till bluffs and was also composed of the finer particles. Both types of clay were relatively impervious and had low shear values when saturated. Removal of this clay from the area under the downstream slope was considered necessary to take advantage of the drainage effect of the pervious material beneath the clay in lowering the saturation line through that portion of the dam. Stripping the clay under the upstream slope was required to increase the factor of safety against sliding.

Borrowpits

Borings in the borrowpits were so planned that they would give detailed information for use in dredging operations. Drilling was carried down to an elevation 5 ft. below the proposed depth of dredge cut. Extreme care was taken in sampling the overburden, to be sure that representative samples were obtained. Drive samples were secured every 5 ft. or oftener, to indicate major changes in the soil formation. Samples were mechanically analyzed in the laboratory by a combination of sieve and sedimentation methods. These analyses, except in a few cases, were carried down to a minimum particle size of approximately 0.004 mm. in diameter. Mechanical analysis was the main test performed on the samples to decide their suitability for dredging purposes and placement in the hydraulic-fill dam. From the analysis of the samples of each hole a set of curves was plotted, giving the cumulative percentages of gravel, sand, silt and clay at various depth (Fig. 8). These curves are used daily in determining the type of material being pumped or to be pumped into the dam. If, for example, the dredge is cutting to a depth of 40 ft. in a material represented by the log of the hole in Fig. 8, then the material pumped will be composed of 4 per cent gravel, 84 per cent sand, 8 per cent silt, and 4 per cent clay.

In addition to the logs of holes and the percentage curves, the results of the borings have been plotted in plan and profile. Plan maps are made for every 10-ft. change in elevation, with additional maps every 5 ft. where there is an abrupt change in the type of material. Soil profiles are made for each row of holes across the valley. Of these two methods for showing the soil formations, the plan view (Figs. 7 and 9) is more widely used by the field men. A coordinate system has been laid out in the field and is used on these maps, so that from the known location of the dredge the type of material being pumped or to be pumped can be easily determined.

As shown by the various soil maps, there are different types of material in different locations in the borrowpits. Some of the material has a high proportion of silt and clay, while in other portions of the borrowpit the material is nearly pure sand; therefore, if more silt and clay are needed for the core, a

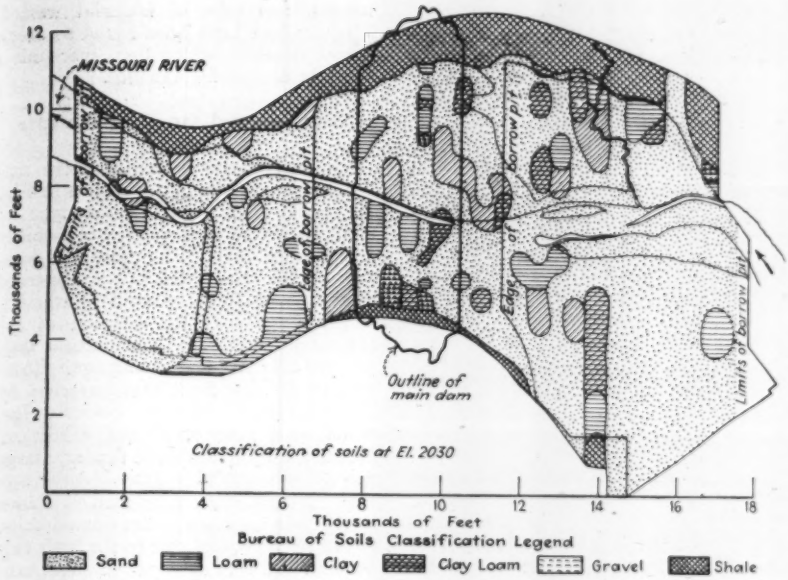


FIG. 7—SOIL MAP of dam foundations and borrowpits on a horizontal plane close to the surface.

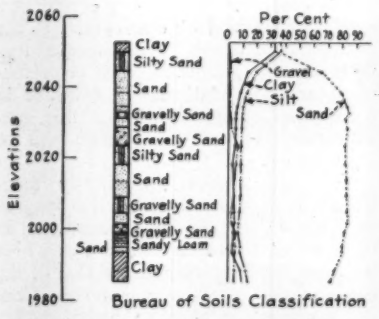


FIG. 8—CURVES PLOTTED for each bore hole in the borrowpits give cumulative percentages of gravel, sand, silt and clay at various depths.

dredge can be shifted to the area where these materials are abundant; and if too much fine material is being obtained, the dredge can be shifted to the part of the pit containing sand.

Dike section

Fig. 11 shows the foundation material under the proposed dike; the upper 125 to 170 ft. is composed of a very uniform glacial till (average mechanical analysis, Fig. 12, curve 5). The till is composed of two distinctly different types, the upper portion a yellowish-brown material while the lower portion is dark gray; and there is a rather sharp line of demarkation between them. These materials probably represent the two periods of glaciation which pushed down across this country. This glacial till upon which the dike will be built is an extremely dense and a relatively impervious soil, but it has certain characteristics that are being investigated thoroughly.

Two plans for the construction of the dike section are being considered at the present time; one is to pump the material from the valley and build a hydraulic-fill section similar to the main dam, and the other is to make a rolled-fill dike of the glacial till itself. To secure further and complete data on which to base a decision, a full-scale experimental dam is being constructed by rolled fill methods. Numerous narrow deep coulees in this vicinity made it possible to select a site close to the proposed dike that gave the desired height with a minimum yardage in the fill and a minimum reservoir capacity. The fill is being placed in approximately 6-in. uncompacted layers and is being rolled with a standard sheepsfoot roller weighing 1,250 lb. per foot of width.

Tests are to be run on this model as soon as it is completed, to determine location of the saturation line, volume of seepage, expansion, shrinkage, stability, and the amount of the soluble salts leaching out of the material. Material placed in the fill of the model is being tested for optimum moisture to produce maximum density, density and moisture content, mechanical analysis, Atterberg limits, shear tests on undisturbed samples, number of rollings required to give the desired density and best depth of layers.

II—Control of Hydraulic Fill

SINCE the placing of a hydraulic fill is purely a mechanical segregation of particles by running water, mechanical analysis has been the principal test on the borrowpit and fill samples. Control of the hydraulic fill is accomplished by making daily tests on the material that goes into the dam. A method for quickly determining the type of material pumped by the dredges is shown in Fig. 8. Borrowpit materials have been so classified that their action when being pumped can be closely estimated ahead of time. Most of the material classified as clay, where it is below the watertable, forms clay lumps or balls when pumped, and is objectionable if placed in either the upstream or downstream banks. Dry clay above the watertable, and all the clay loams, disperse rapidly when they are pumped through a long line, and therefore furnish an excess of core material. These clay and clay-loam strata are avoided where possible, since they

FIG. 9—SOIL MAP of dam foundations and borrowpits on a horizontal plane near the bottom of pits.

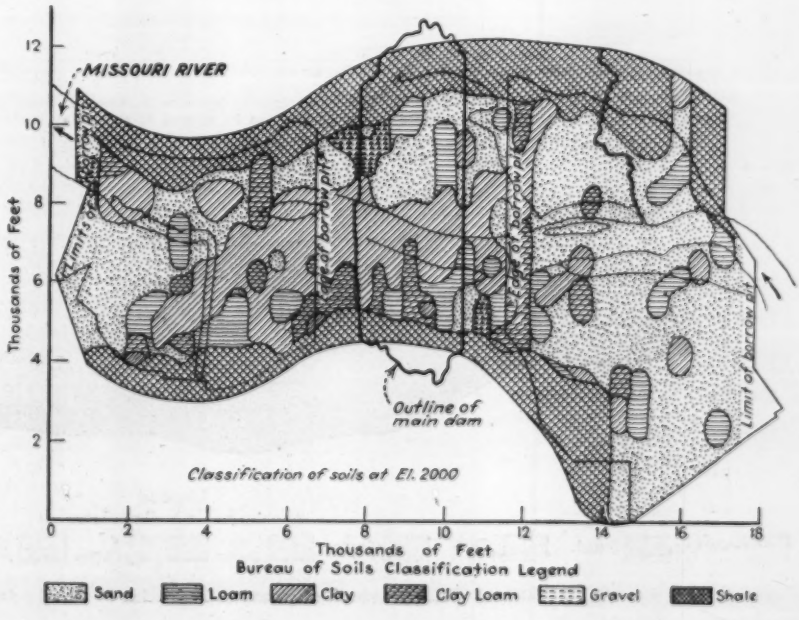


TABLE I—TYPICAL DAILY SUMMARY SPOIL REPORT

	"Gallatin"	"Jefferson"	"Madison"	"Missouri"	Average
Discharging into fill area	2	1	4	4	.....
Wasting over spillway No.	1	1	3	3	.....
Velocity in pool, ft./sec.	1.8		0.8		1.3
% solids in waste	0.93		0.54		*0.74
Material wasted					
sand	7.3		7.0		7.2
silt	26.8		23.0		25.3
clay	65.9		70.0		67.5
Amount dredged, cu yd.	32,830	34,430	43,690	33,740	144,690
% of total today	22.7	23.8	30.2	23.3	.....
Effective time	20 hr. 53'	22 hr. 16'	22 hr. 27'	23 hr. 40'	22 hr. 19'
Output, cu. yd. per hour	1,572	1,546	1,946	1,426	1,621
Velocity in pipe line, ft./sec.	20.3	19.4	19.8	21.6	20.3
% solids pumped	13.5	14.0	17.3	11.5	14.0
% of pumped solids wasted	7.2	6.3	4.1	3.7	5.2
Material pumped					
gravel	1.0	23.0	0.0	4.0	6.6
sand	83.9	63.0	91.0	88.0	81.8
silt	8.0	6.0	3.0	3.0	4.9
clay	8.0	8.0	6.0	5.0	6.7
Material left in dam					
gravel	13.1		1.9		7.0
sand	77.5		92.9		85.8
silt	5.6		2.2		3.8
clay	3.8		3.0		3.4

*0.5 deducted for solids carried by the river.

supply more core material than is desired, and for that reason the losses are greatly increased.

In order to keep a close check on the type and amount of material being placed, a daily dredging report is made covering the work of the four dredges. A typical report is shown in the accompanying table. Velocities in the core pool are obtained by the use of floats, and are used along with the depth, width and length of the pool as an aid in controlling the core material. Per cent of solids in waste is determined by taking daily samples from the spillway discharge. These samples are then analyzed by the laboratory for suspended solids and distribution of grain size. Dredged volumes are determined by cross-sections taken before and after dredging. Per cent of solids pumped is determined from this figure by the use of the average daily velocities.

Permanent velocity stations have been set up on each dredge line, and the velocities are determined daily by means of the injection of a salt solution at a given point and picking it up several hundred feet down the line by means of two electrodes. Per cent of pumped solids wasted is then determined by dividing the per cent of solids pumped into those wasted over the spillway.

Where the volume of the waste water is materially less than the volume pumped, due to seepage through the banks, a correction is made in the per cent of solids wasted. This difference in volume pumped and volume discharged over the spillway will increase as the height of the fill increases, since the volume of seepage through the banks will increase with the head. Types of material remaining in the dam are computed from the types of material pumped, per cent of pumped solids wasted, and type of material wasted. These values have been found to check very closely with the mechanical analysis of the fill samples.

Sounding and sampling the core

Limits between which the core material is being placed are shown in Fig. 2. Factors that govern the type of material placed in the core are stability and permeability. Therefore the location of the coarse limit was governed by the allowable permeability coefficient, which determines the position of the saturation line in the downstream shell and the total volume of seepage. Location of the fine limit was governed by the estimated rate of consolidation, which is a function of the stability.

It is highly undesirable that any large amount of material be placed in the core that contains more clay than is shown by the fine limit, since the consolidation would be very slow due to the high clay content. In this case only a small proportion of the ultimate consolidation would be taken up during construction; therefore, the consolidation of the core would continue over a long period at a rate which would be detrimental to the completed structure. It is expected that with any type of puddle core the settlement or consolidation will continue to occur after completion, but if this consolidation is small no trouble will be experienced.

The daily report, previously mentioned, is supplemented for the purpose of control by numerous soundings in the core to determine the rate at which the core is filling up and the rate of the consolidation of the soft material. Control samples are taken at various depths

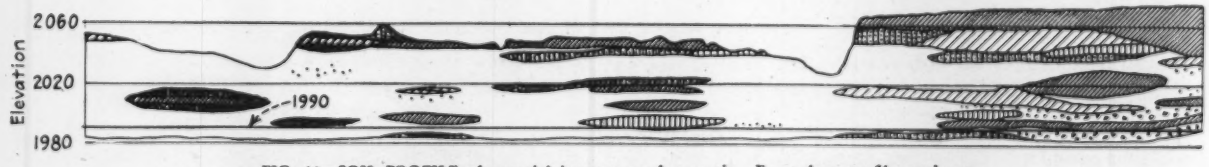


FIG. 10—SOIL PROFILE of material in upstream borrowpit. From these profiles and corresponding soil maps, the dredges can be spotted to pump any desired borrowpit material.

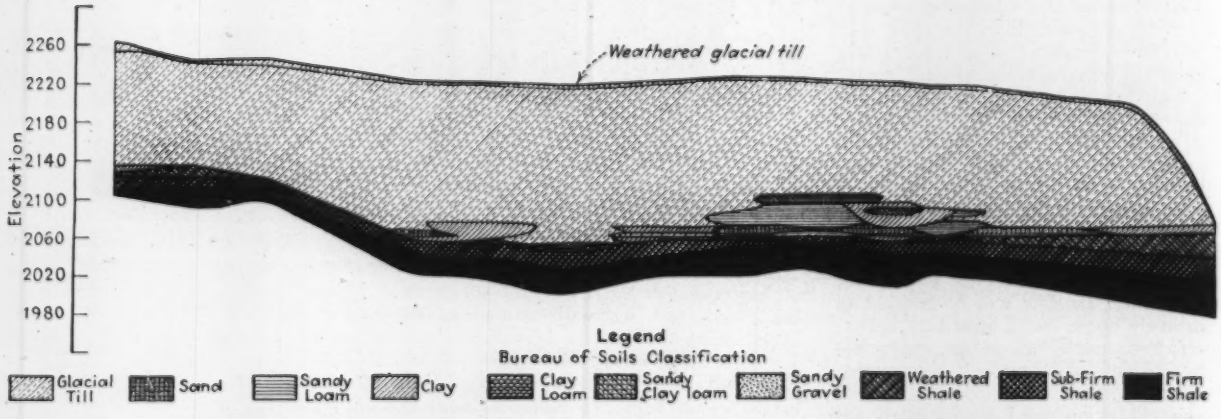


FIG. 11—SOIL PROFILE to bedrock of ground under location of the dike flanking west end of main dam.

and locations in the core in order that a close check may be kept on the core material being placed at that particular time and on that material which is remaining as a partly consolidated mass. Only two routine tests are run on these samples: mechanical analysis and moisture content. Tests for grain size are carried down to a minimum diameter of approximately 0.004 mm. Numerous tests in the district laboratory have confirmed the use of the effective size as a means of estimating the permeability coefficient, and they have also proved that the clay content is indicative of the shear value (stability) of a given material.

In addition to the control samples taken of the core material, permanent record samples are secured every 5 ft. in elevation, at each 100-ft. station, and each 50-ft. range, which makes one sample for every 925 cu.yd. These permanent samples are taken deep enough into the partly consolidated core material to be certain that the material will not change.

Sand cross-dikes

Control of the core is made somewhat more difficult, since it is necessary that the fill be placed on both sides of the river to El. 2,150, leaving the river section open until the diversion tunnels are completed. It is obvious, therefore, that a partly consolidated core having a maximum height of 100 ft. must be held back until the closure is made. To do this, plugs of stable material are essential at the river ends of the core. These plugs must be of sufficient section to withstand the core pressure, and at the same time must be sufficiently impervious to prevent excessive seepage through that portion of the core. It was found that any material that could be placed with dredges and that was comparable to the main core material as to imperviousness was not stable enough to give the desired factor of safety against failure in shear. The plan adopted embodies the placing of sand plugs 550 ft. wide at the base (El. 2,050) and 50 ft. wide at the top (El. 2,150) with the foundation sheetpile cutoff wall carried up through the plugs and extended into the regular core material.

Shear, consolidation and permeability tests are being made on the core material at frequent intervals. Shear tests are made on all materials, to check the stability of the plugs and the upstream slope against the pressure of the partly consolidated core. The consolidation tests are being made to estimate stability and permeability after partial consolidation, and to estimate the rate of consolidation to be expected during and after construction. The permeability tests are being made at the degree of the consolidation that is expected to occur when the entire fill has been placed above the location of the sample.

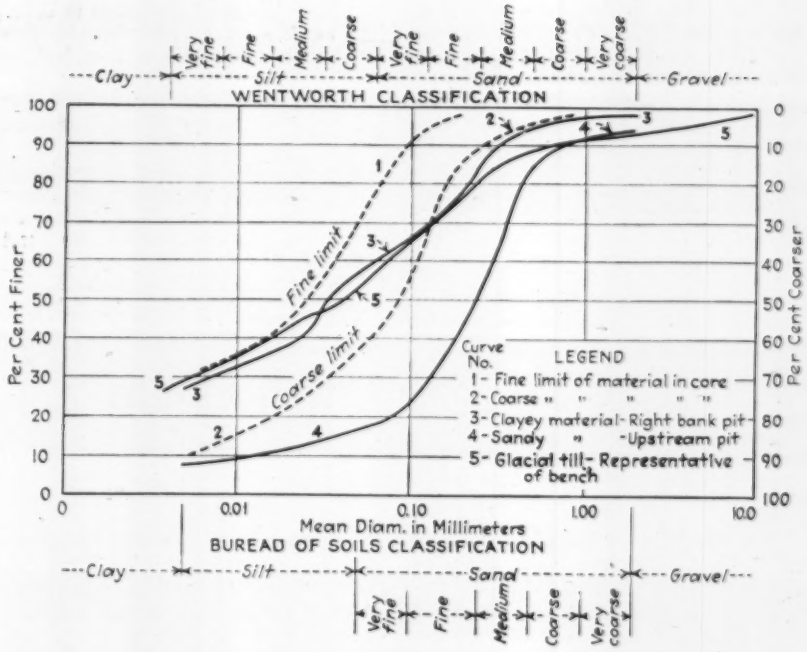


FIG. 12—CURVES of average mechanical analysis of classes of materials found in the various borrowpits, and of limits of fines of core material.

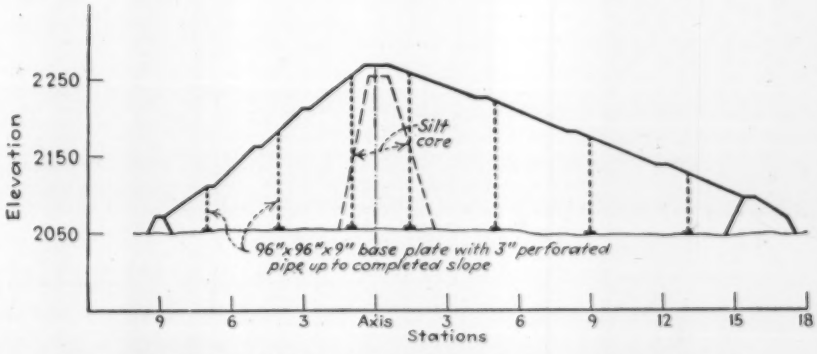


FIG. 13—SUBSIDENCE PLATES and seepage-determination pipes are located in several transverse rows across the dam, arranged as shown in this typical section.

Control of the shell is a relatively simple matter compared with the core, but it should by no means be neglected. Fewer control samples are taken from the shell than from the core during normal operation, since the general run of material is good sand. Near the maximum limits of the core pool, especially on the upstream side, it is necessary to check the material remaining in the shell, as the stability of the upstream slope would be greatly reduced if a layer of soft core material should be allowed to remain in the shell. Deposition of fine material in the downstream shell is of less concern as to stability, but it is important as to the location of the saturation line. The material in the downstream shell is being maintained coarse enough to assure relatively free drainage of the seepage waters away from the core.

Deposition of any great quantity of clay lumps or balls is not tolerated in either the upstream or downstream shell, since they will materially reduce the stability of the former and the rate of permeability through the latter.

Permanent record samples of the shell material are taken every 5 ft. in elevation, at each 100-ft. station and 200-ft. range. This gives one sample for every 3,700 cu.yd. These permanent record samples are mechanically analyzed for grain size and stored in the laboratory to be available for reference at any time.

Settlement plates

Seven settlement plates have been installed along each of five sections perpendicular to the axis of the dam. Each section includes three plates in the downstream shell, two in the core and two in the upstream shell. These plates are connected to a 3-in. pipe, which is extended as the fill is built. The pipes are perforated, so that they can be used for locating the saturation line through

the dam. Fig. 13 shows the location of the pipes and plates on a typical cross-section of the dam. Consolidation tests are being conducted on the foundation material, to estimate the rate and the ultimate amount of consolidation that will occur. These results will be checked against the actual settlement occurring during construction, and from them the ultimate consolidation of the foundation can be closely estimated.

Permeability tests on the shell and core materials are being made in order that the location of the saturation line can be estimated. These tests will be used for control as well as for a basis of comparison of the actual saturation line with the computed or theoretical line.

The district laboratory is in charge of N. T. Stadtfeld, engineer; the writer is in direct charge of all field work in connection with soil explorations and tests.

Stripping the Base of the Dam

Over 4,000,000 yd. of gumbo removed down to stable subsoil by graders, shovels and fast motor trucks in a high-speed operation

AS ALREADY recounted (p. 286), the foundation studies indicated that complete removal of all material down to stable subsoil strata was necessary over the entire area of the dam. This stripping was also desirable for starting the hydraulic fill on a substantially level bed. One of the first operations was stripping the dam site of an overburden of some 4,000,000 cu.yd. of gumbo topsoil from 3 to 30 ft. deep. This work was let to contract for completion in 250 days. In 120 days the contractors had excavated 4,100,000 cu.yd., and in 30 more days had cleaned up and moved off of the job.

The major equipment consisted of nine elevating graders pulled by diesel tractors, three shovels, three draglines and a fleet of 250 light and fast dump trucks. The graders loaded 500 cu.yd. per hour, and the trucks ran at speeds up to 40 m.p.h. Shovels and draglines dug out the corners and the deeper end sections, allowing the graders to concentrate on long straight runs. In two seven-hour shifts the graders loaded 55,000 cu.yd. for the highest day's run; in the peak month, 1,157,000 cu.yd. were removed.

The Missouri River split the work into two main sections, and an island at the site made a third minor section. The island was worked with the smaller or west bank mainland sector, two earth embankments thrown across the stream channel providing access from the mainland.

The map (Fig. 14) shows the layout of the operations. Where possible grader units worked crosswise of the site, except along the trestles. The procedure was considerably affected by these trestles, most of which were under construction at the time. Wherever it was possible to work out a straight run long enough to give the units a chance to produce, the elevating graders were used. Usually a strip 200 ft. wide was assigned to a grader and its accompanying fleet of trucks. In the deeper grader cuts often two or more units would work in tandem, following close behind each other.

The draglines and shovels attacked the deeper cuts at the foot of the bluffs on each side of the river. While this work was slower, the total yardage was much smaller than that on the flats, permitting completion along with the grader work. The heavy equipment was also brought into play in working out the topsoil under and alongside the trestles. On part of the trestle work the contractor managed to strip ahead of the piledriver.

The contractor was the Addison Miller Co., St. Paul, Minn., with H. C. James as superintendent in charge.

PREVIOUS ARTICLES ON FORT PECK PROJECT

Preliminary work	Apr. 5, 1934, p. 444.
Economics and general features	Nov. 29, 1934, p. 693.
Sheetpile cutoff wall	Jan. 10, 1935, p. 35.
A year's progress	May 9, 1935, p. 659.
Diversion-tunnel driving	May 23, 1935, p. 735.

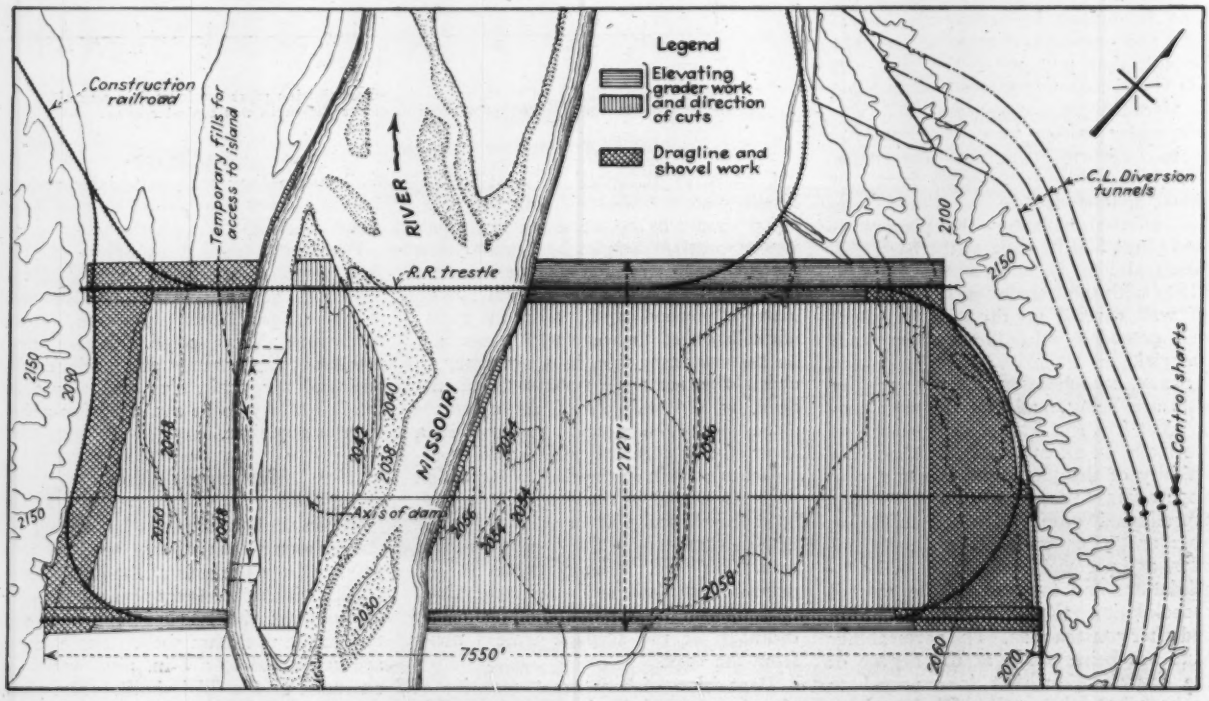


FIG. 14—ELEVATING GRADERS on cross-site runs covered most of the base of the dam in stripping operations. Outside the trestles the graders paralleled the structures. Deep end cuts were removed by shovels and draglines.

Steel Sheetpile Cutoff Wall

Rolling tower piledrivers, long-boom cranes, and hydraulic spade jets sink steel sheeting 150 to 190 ft. through glacial till to bedrock

IN PLACING the diaphragm of steel sheetpiles to cut off seepage under the dam the principal problem lay in the depth of driving, from 140 to 190 ft., through soil overburden to shale bedrock. About two miles of cutoff are required, the wall extends from high on the east abutment across the width of the valley to high on the west bank. Here four additional lines of sheeting are being driven as range walls up the troughs of small coulees in the west abutment to seal off the glacial till that comprises this side of the valley. About all of the sheetpiling is now in place, with the exception of the main wall on the west abutment, which is being driven at the present time.

General features of the piledriving and design of the wall were described in *ENR*, Jan. 10, 1935, p. 35. Principal driving equipment consists of three wide-gage traveling gantry towers, 190 ft. high, which handle water jets, the piles and hammers. All hammers, double-acting steam type, are operated by compressed air. Long-boom crawler cranes assist in handling jets and piles and are used exclusively in driving the four range walls.

Each long pile is made up of two shorter lengths, one of which is dropped into a previously jetted hole (usually to full length of section), and to which the top section is welded. The spliced full-length pile is then driven to grade in pairs. The contractor attributes the success of the deep driving to the rolling tower rigs, and particularly to two types of hydraulic spade jets that facilitate the driving.

One type of spade consists of two 4-in. jet pipes split into a manifold of three nozzles close to the lower end. Three hard chisel bits welded to the sheetpile extend below the jet openings. This was the first type to be built and was in successful use across the valley floor.

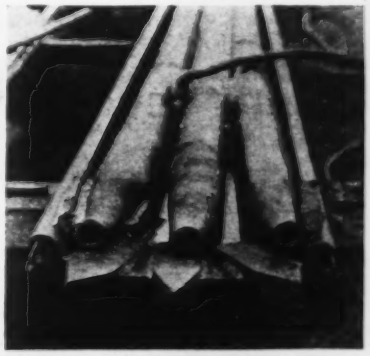
The second type, regarded as even more successful, consists of a single 4-in. jet pipe entering a pocket at the foot of the pile section formed by welding a plate over the depressed arch section of the pile. Spacers placed around three lines of rivets separate the plate and the web of the pile, thus dividing the pocket into four vertical channels. Five chisel teeth extending below the pocket plate form between them four ½-in. openings for the discharge of the jet water. There is also a small opening in the jet pipe where it enters the pocket, designed to relieve the friction at the foot of the pipe. Another discharge hole is cut into the side of the pile at the interlock to relieve friction here.

First sections jetted down

Water is forced into these spade jets at 200-lb. pressure. The spades are handled by the gantries only, as they are too heavy and long (190 ft.) for the cranes. The routine operation is to set the spade in the interlock of the last-driven pile and jet it down to grade if possible. This often takes several hours. The spade washes out a channel alongside the completed pile, into which the first of two lengths making up a full length pile is dropped. This first section, 70 to 80 ft. long, usually drops its full length before friction overcomes its weight. The top section is then welded on. The full-length piles are driven down in pairs by double-acting hammers operating on compressed air.

During driving operations round jets

HYDRAULIC spade jets developed for driving long sheetpiling. The type shown at the top is fed by two 4-in. jet pipes; that below has one jet-pipe feeding into a narrow box formed by welding a plate over the arched web section of a standard piling.



THREE MILLION YARDS of sand and silt per month are being pumped into the dam through 28-in. pipe lines by four dredges. Spilling the discharge upon plank tables spreads the flow and reduces beach erosion.

with nozzle points are sunk along the faces of the two piles under the hammer. On the range walls being driven up the four coulees on the west abutment and on the high east end of the main wall, where gantries could not be operated, round jets handled by cranes are used exclusively.

In the corewall across the river, left out when the main wall was driven across the dam site, a gantry rig traveling on two trestles drove the piles to grade with the tops usually remaining several feet out of the water. A diver, with an underwater cutting torch of the d.c. electric type, cut off the piles in the river channel 12 ft. below water level, to permit navigation of the floating plant for the next two years. Eventually, when the river is diverted, splices will be welded onto these sections of piling to bring the corewall up to the level of adjacent sections.

A gantry is being used on the steep west bank abutment section. The gantry frame was cribbed up on the downhill trucks to compensate for the 22 per cent slope. The rig is anchored and is hauled by a heavy cable attached to deadmen at the top of the slope.

Contract for the sheetpiling is held by the Frazier-Davis Construction Co., and G. L. Tarleton, of St. Louis, Mo., Chas. Gove and H. F. Snowden are superintendents. Capt. C. H. Chorpening is in charge for the government.

Placing the Hydraulic Fill

Plan of pumping operations and order and results of filling operations as determined for first dredging season

PUMPING steadily day and night, seven days a week, four hydraulic dredges are placing from 115,000 to 150,000 cu.yd. of material daily, building up the 100,000,000-yd. fill required for the dam. With this progress, the dam is beginning to take shape, and operations are assuming a routine following three months of filling the valley floor (the hollows and corners) and getting the dredging work lined up in scheduled form.

Last fall a total of 843,300 cu.yd. was pumped into the dam. Starting dredging operations again this year on April 14, a total of 12,600,000 cu.yd. had been placed to Aug. 15, including last fall's yardage.

Reason for hired-labor construction

All dredging and filling operations are being carried on directly by the government on a day-labor basis, using plant owned and for the most part built on the job under the direction of the engineers. The reasons for building the dam by day labor, while almost all other work on the project is on a contract basis, were weighty.

Control of materials and coordination of operations are of prime necessity. The size and height of the fill indicated unusual construction hazards. Moreover, weather conditions in the northern Montana district are unusually rigorous and there was uncertainty as to a performance period that would be equitable and satisfactory to contractors and still be to the best interests of the government.

These considerations made impracticable specifications for the work which would satisfy the requirements of the Comptroller-General for a formal government contract. All things considered, it was decided best by those in charge to resort to day labor on the main dam operation.

Building the gravel toes

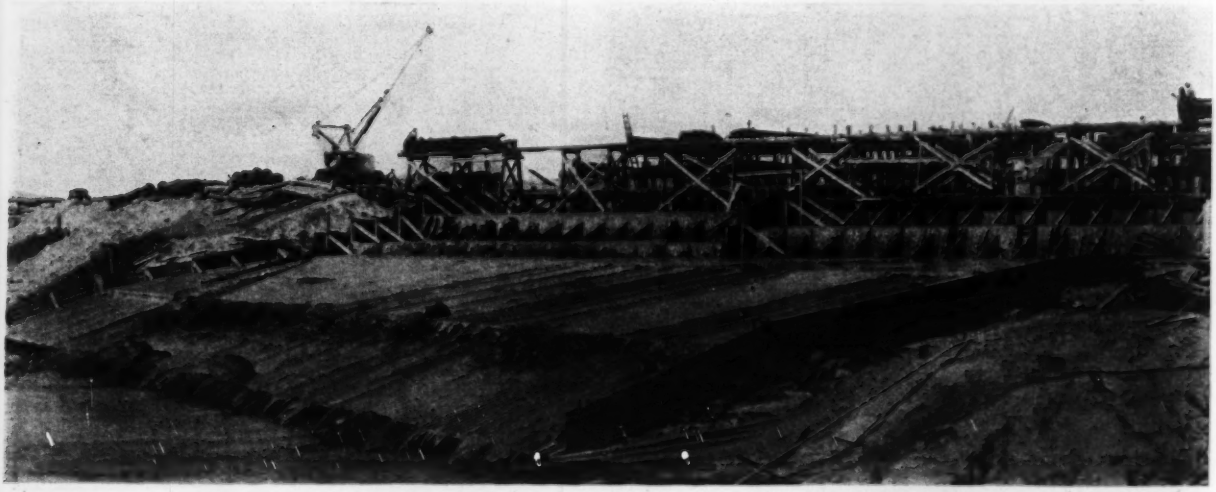
The dam site was cleared by hired labor during the winter of 1933-34, and a year ago this last spring the 12-mile railroad connecting the site with the main line of the Great Northern at Wiota was completed. To provide access to the right-bank operations, this railroad was extended across the Missouri River on a steel and wood trestle along the center line of the downstream gravel toe, and ultimately by additional trestles to include an elevated loop encircling the dam site at the base of the bluffs on both sides and along the center line of the upstream gravel toe, except that a gap was left at the river channel on the upstream trestle.

Gravel and rock for the toe fill are dumped directly from these trestles. The gravel for the toe fills is ½ to 6 in. in size, all materials below and above these size limits being screened out and wasted; it is obtained from extensive glacial deposits at Cole, Mont., 80 miles from the dam, and is transported to the dam in bottom-dump gondola cars (p. 305). The gravel is dumped through the trestles, and on the lower toe the downstream flat slopes of the fill are spread out from the trestle dump by bulldozers. The dumping requires only 0.9 min. per car on trains of 70 cars, and the highest average per train was only 2.5 min. per car on the coldest nights.

In suitable weather the gravel is washed, but to keep the work going through the winter the washing was omitted during cold periods. At times the temperature reached 36 deg. below zero, but gravel dumping never stopped.

Dredging plant and plan

The dredging plant comprises four identical units. Each consists of (*a*) a wood-hull dredge containing two 28-



WASTE WATER from the core pool, carrying from 2 to 6 per cent of fine materials, cascades down 5-ft. steps in staggered 79-ft. wooden sluiceways.

QUICK-ACTING toggle connections permit fast changes in the ball-and-cone joint pipe lines used on the embankments.

in. pumps, direct-connected to 2,500-hp. electric motors, set in tandem and discharging through a 28-in. pipe line: (*b*) a floating booster plant containing two pumps, also in tandem, identical with the dredge pumps; and (*c*) a land booster plant, mounted on rails, with one 28-in. pump, identical with the other pumps. Accessory plant consists of 375 pipe pontoons, 16 elbow pontoons, 200 power cable pontoons, two 25-ton derrick boats, one 210-hp. diesel towboat, seven gasoline motorboats, four landing barges, four anchor barges, and two car ferry barges for transferring the land boosters.

With the exception of one large towboat, and some of the launches, all the floating plant was either built or assembled at the site in a boatyard on the left downstream bank. The four dredges have been named "Gallatin," "Jefferson," "Madison" and "Missouri," and will be referred to by name when describing the various dredging operations.

Because the time required to drive and line the four diversion tunnels necessitates keeping the present river channel open until the summer of 1937, for the first two years the dam will be built in two sections, one on each side of the river. The river flows northward through the site, and the channel is much nearer the west side of the valley floor. This divides the dam into two parts, about two-thirds of the area of the base lying on the east side of the river. The steel cutoff wall and core pool further divide each section into two parts, of which the downstream part has about double the volume of the upstream part. Thus, in the early period of the hydraulic-fill work there are four main pumping areas—an upstream and a downstream sector on each side of the 800-ft. river opening.

Until such time as the river closure is ready, the ends of the cores at the river banks are being held by sand dikes built up of the same dredge material as the outer embankments, or beaches, of the dam. These dikes, with a maximum base width of 700 ft. and riverside slopes of 1 on 4, are built up by draglines from material discharged from near-by pipe lines and will remain in place after river closure. A waterstop through the dikes will be provided by welding extensions to the sheetpile corewall as the fill rises. It is expected that the dam will reach a height of 100 ft. before the river is closed.

In the summer of 1937 it is planned to divert the river through the tunnels, close and fill the present channel and from then on hydraulic-fill the dam embankment full length. Plans for the current filling operations, while the dam is divided by the river into two parts, call for the dredges to work from the upstream borrowpits, two on each side of the river. After the river gap is closed, the dredges will be moved to the downstream side and the fill completed from the lower pits.

The dredges were launched in the summer and fall of 1934, and 843,000 cu.yd. of material were placed in the dam in November and December; dredging stopped Dec. 23. On April 14, 1935, the fleet was taken out of harbor, though ice was still running strong in the river. Difficulty was encountered in moving the heavy dredges with the small tugs available, as the large towboat ordered for the purpose from the Gasconade, Mo., boatyard had become ice-bound in South Dakota and never reached Fort Peck until May. Shifting sand bars in the river channel blocked the dredges, and several times they had to be put in operation to cut their way through; this necessitated the building of temporary power feeder lines and pipe lines.

Upon reaching the upstream borrowpits, the "Jefferson" and "Madison" were assigned to dredging out slips, one on each side of the river at right angles to the channel, for the floating booster plants. These slips are 300 ft. wide; that on the left bank is 3,000 ft. long, and that on the right bank 1,000 ft. long. In the meantime the other two

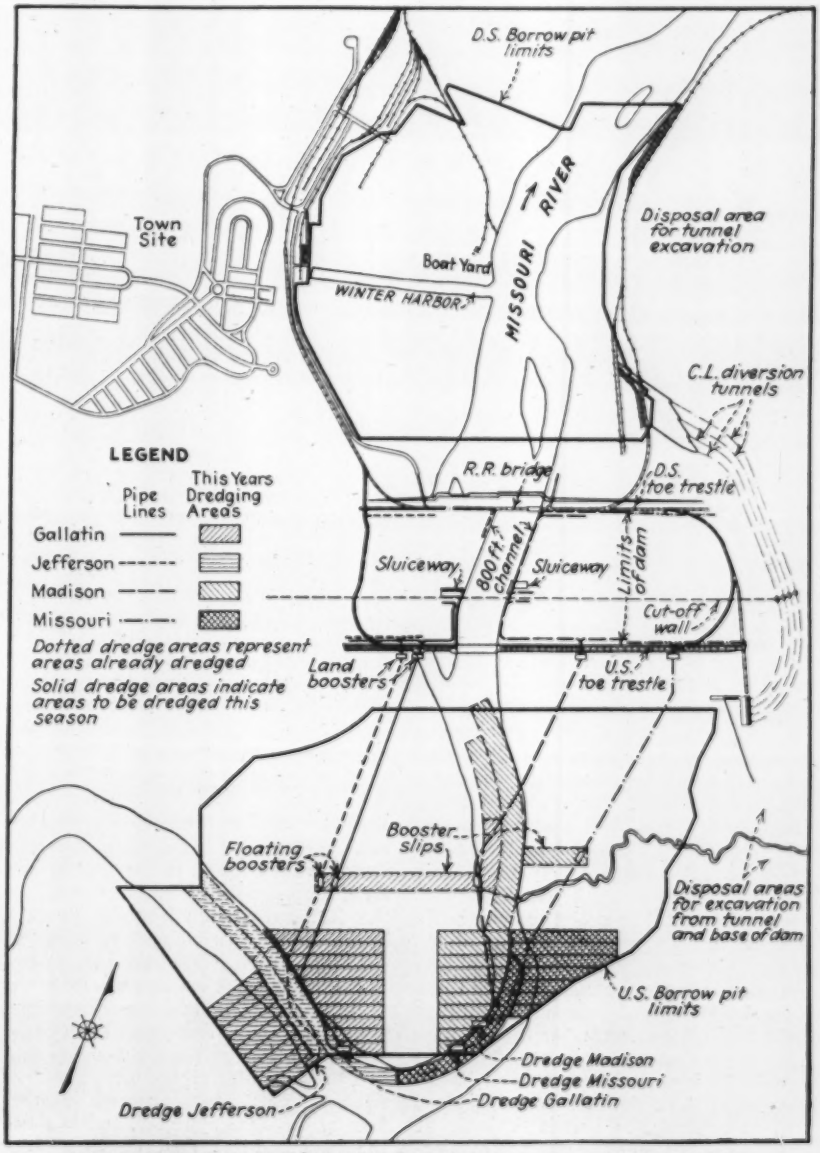


FIG. 15—DREDGING OPERATIONS will be carried on from upstream borrowpits until the summer of 1937. Each of the four dredge units has been assigned to definite borrowpit areas, and pipe lines were laid out accordingly.

dredges were working in the river channel.

The layout of the dredges as they are located at present and will be in general for this and next season is shown in Fig. 15. On the upper reaches of the left-bank borrowpits are the "Gallatin" and "Jefferson," while the "Missouri" and "Madison" are on the opposite side of the river. The dredging areas designated for each unit are general only, as any unit may be shifted if needed to dig into materials of desired characteristics.

Pipe-line layout

Three types of dredge discharge pipe, most of it 28 in. in diameter, are in service: (1) floating, with flexible steel ball-and-socket joints; (2) extra heavy with bolted flange joints for the long reaches across land from dredges to dam; and (3) lighter ball-and-cone joint pipe with quick-acting toggle connectors for the discharge ends across the fill. Some of this latter type is 21-in. and 16-in., for use with Siamese connections. The quantities of pipe line on hand are: 28-in. floating, ¾-in. shell, 10,300 ft.; 28-in. flanged, ¾-in. shell, 26,600 ft.; 28-in. ball and cone, ½-in. shell, 16,500 ft.; 21-in. ball and cone, ½-in. shell, 10,300 ft.; and 16-in. ball and cone, ¼-in. shell, 10,000 ft.

As the present semi-permanent position of the dredges was planned in advance, the winter months were employed in building up the flanged-joint pipe line across the land between the borrowpits and the upstream toe of the dam. These lines were built to exact line and grade by laying them on wood blocking or on short timber bents. They are set to a grade, to permit draining at various points and the expense of placing to careful line and grade is believed to have been justified by reduction in friction head and in wear of pipe.

At first, pipe lines to the downstream beach were run across the dam site on temporary trestles. Other temporary lines were run into corners and low spots for early filling. By the middle of July, when the beaches were fairly uniform for their full length, the pipe lines were placed as shown in the plan (Fig. 15) for the remainder of the current season. The plan provides that the "Jefferson" and "Gallatin" will pump into the left bank area, serving both beaches, the "Jefferson's" pipe being carried around the left bank on the railroad trestle to the downstream beach, while that of the "Gallatin" extends along the river to the core pool sluiceway area. Because of the larger area of the right-bank section, the lines from the "Madison" and "Missouri" have been connected to the upstream discharge pipe, and both are extended to the downstream beach. Those of the "Madison" follow the river bank, while the "Missouri's" line is carried on the right-bank railroad trestle.

SINGLE PUMPS on car boosters give a final push to the pumped material as it enters the dam. Note the accurate grade and alignment on the flanged land-pipe sections. Care was exercised in fixing line and grade to reduce wear on the pipe.

Booster units

Three of the double-pump floating booster units are located in the left-bank slip, the fourth in the shorter slip on the opposite side of the river. At the dam end of each land line is set a land booster, a single-pump unit mounted on a car. Thus each of the four dredging units consists of five pumps. At present, because of the low head being pumped against, and even though the discharge lines run from 9,000 to 14,000 ft. in length, all five pumps are not needed. One pump on each floating booster has been bypassed, and at times the land boosters float on their lines without pumping, though they are never cut out entirely.

To serve the dredges and booster units, a grid power-line system of poles has been built in the dredge area, the lines crossing the river on steel towers on a 1,000-ft. span. Power is supplied at 6,600 volts from a substation on the west bluffs. Heavy insulated conductor lines on light pontoons form the power connections to the floating equipment.

Dredging operations

Each of the four dredges works a cut 200 ft. wide. The cutter head, on a 75-ft. ladder, is kept 45 ft. below water surface. Through anchor lines, the cutting end of the dredge is swung back and forth, turning on one spud. When in or close to the river channel, the dredge may work for a considerable time in one position, for the river keeps filling up the dredged hole. A vacuum as high as possible, about 24 in. in this altitude and under the working conditions, is maintained on the suction line. A high vacuum is also maintained in the booster pumps, a departure from normal dredging operations.

Experience has shown that a velocity of 21 to 23 ft. per sec. in the pipe lines is most efficient. The pumps have been speeded up to produce velocities as high as 30 ft. per second, but it was found that less solids were pumped at this speed than at lower speeds. Velocities are measured in the land lines by the salt method, as described on p. 288. Varying with the character of materials being pumped, the solids average 15 per cent of the pumped volume. The speed of the pumps can be varied, and a constant torque is maintained by an electrolyte rheostat.

It is too soon yet to ascertain the rate of erosion of the pipe lines; although at some bends and joints excessive wear has occurred due to unusual conditions of turbulence, these were easily repaired by welding.

Measurements of pipe line friction losses have been made over only a narrow range of velocities and only for one 28-in. size of pipe; therefore complete data for a friction-loss equation are lacking under average conditions of operating. Assuming the equation will approximate that of Darcy's modification of the Chezy formula, $H_f = \frac{flv^2}{d2g}$, it appears that the factor f for new straight-flanged pipe land lines is about 0.011, and for the special type of ball and cone fill lines is about 0.012. In the ball-and-socket floating lines it has been difficult to determine what proportion of the line loss is due to friction and what part is due to bends. Measurements on the floating lines gave values of losses varying from 4- to 7-ft. head of water per 100 ft. of line at 20 ft. per sec. velocity, but this includes losses due to bends.

The head losses in the floating line have not been found to differ greatly

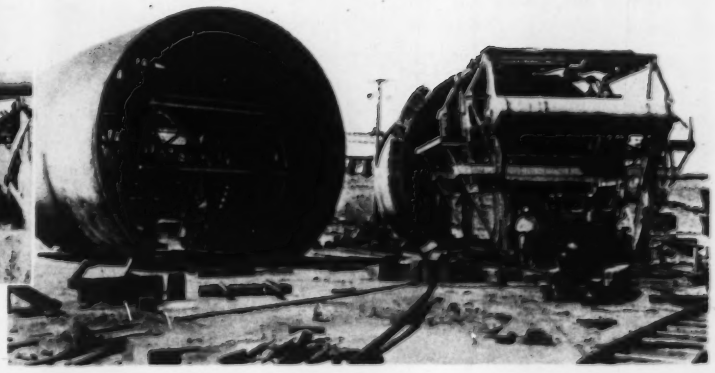
Construction Views of

FORT PECK PROJECT

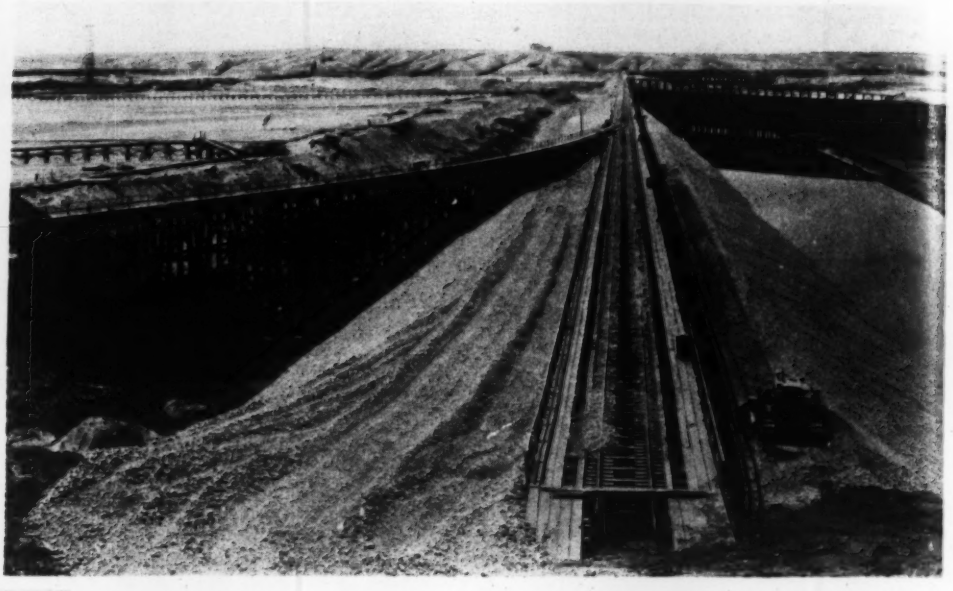
WINTER employment was provided by the laying of long reaches of flanged land pipe between borrowpits and the dam.

AIR VIEW of the trestle encircled base of Fort Peck Dam as hydraulic filling was starting.

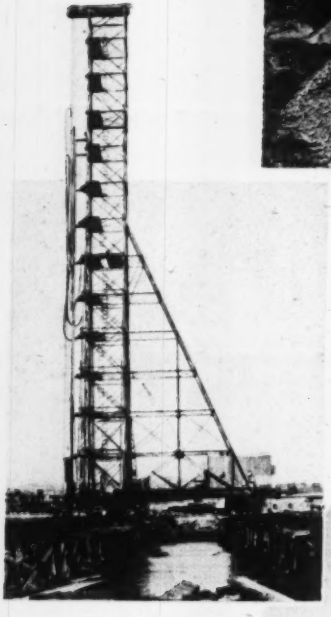
MAMMOTH STEEL FORMS and twin-gun concrete-placing units are used for installation of lining in the 32-ft. diversion tunnels.



BUSINESS END of one of the four rail-mounted land booster units that give the dredged material a final kick into the dam. The 28-in. pump is 7 ft. in diameter.

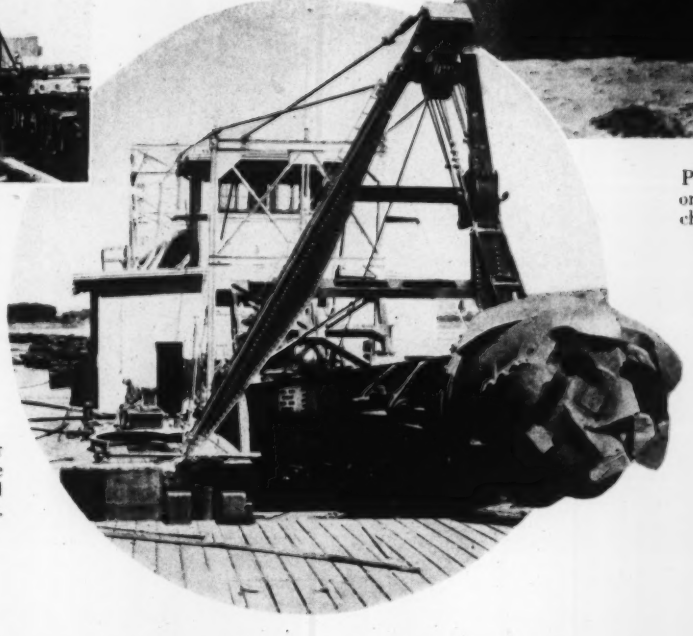


MILLIONS of yards of graded gravel are required for the toe fills of the main dam. Bulldozers spread the material to a wide base as it is dumped through the trestles from bottom-dump cars.

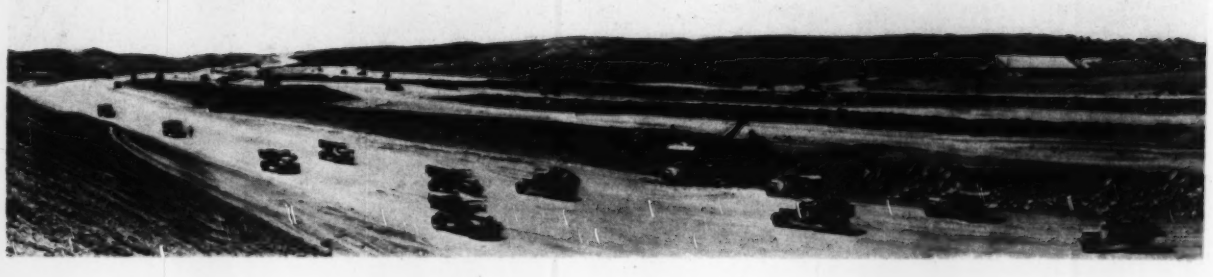


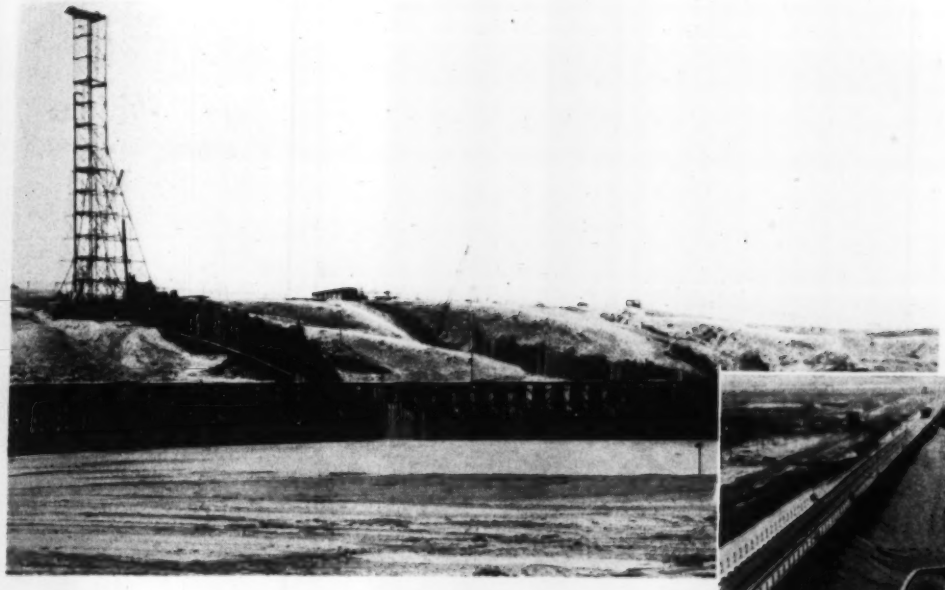
CLOSING the river gap in the sheetpile cutoff wall with a gantry traveling on two trestles. The sheets are cut off at riverbed level, to permit job navigation for two seasons.

PUMPED MATERIAL from one of the four dredges discharging upon a table to spread the flow across the beach.

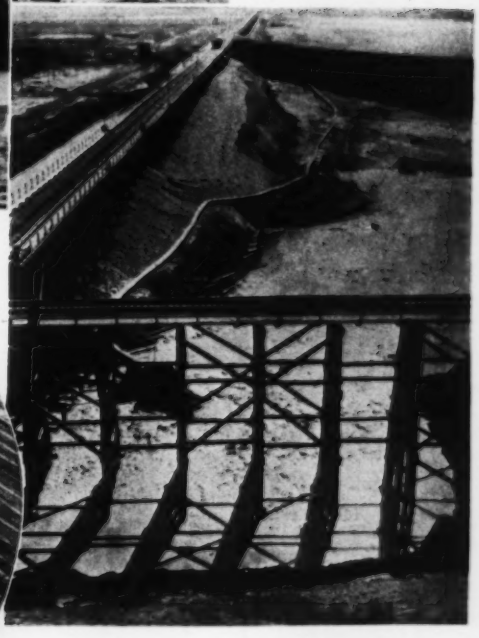


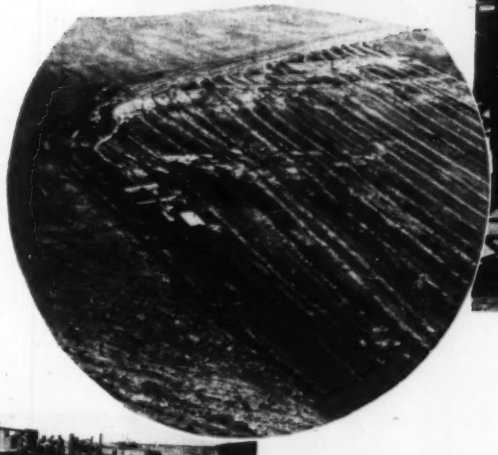
THE basket-type cutter heads on the dredges are 7 ft. in diameter, designed primarily for soft digging.





A 200-FT. tower gantry climbs the steep west abutment in driving the 190-ft. steel piles for the cutoff wall. A crane driving one of the four steel rangewalls is in the background.



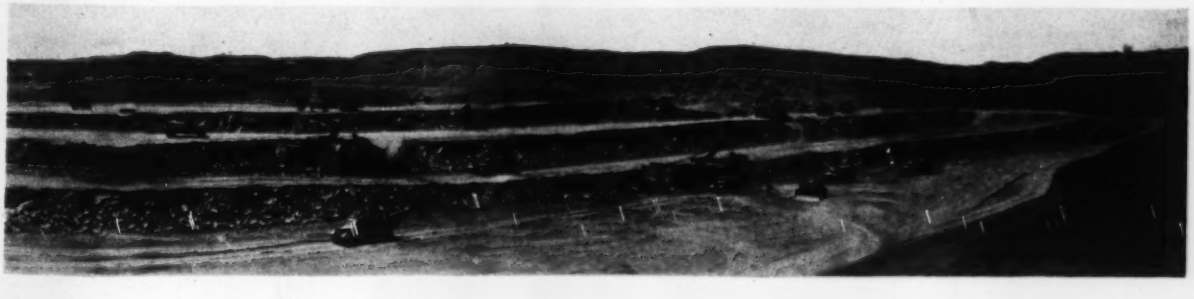


ALMOST STANDING on its nose, the tractor and grader outfit rolls down the steep side slopes of the spillway cut, leaving a nicely trimmed surface behind it.

PUMPING into a corner pocket of the dam with a temporary pipe line.

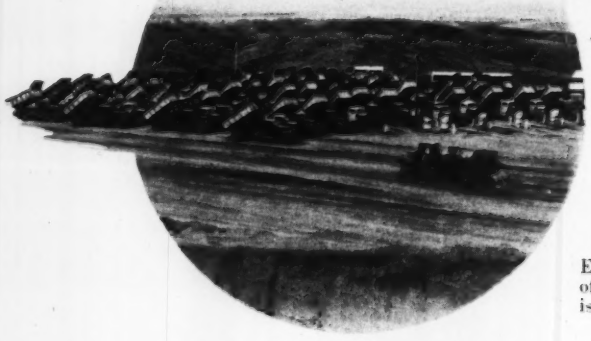
WASTE WATER from the core pool cascades down the stepped wooden sluiceways.

PANORAMIC VIEW of the mass attack on a 10,000,000-yd. section of the spillway cut by a battery of diesel shovels and a fleet of fast 8-yd. trucks.

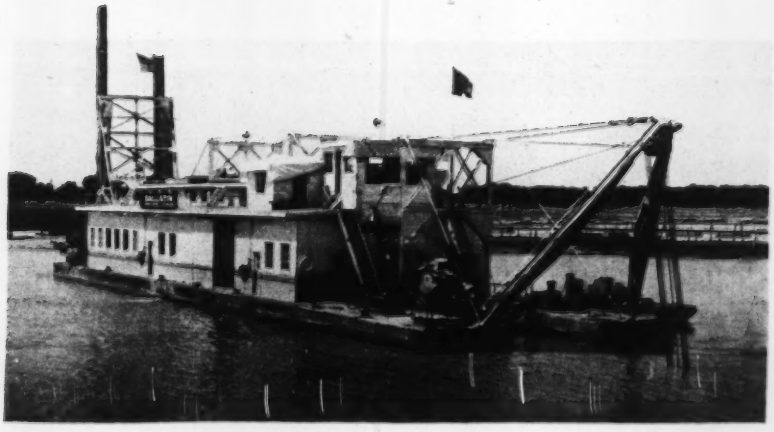


RETAINING WALLS and short cut-and-cover sections are required at the outlets of the four diversion tunnels to restrain the shale bluffs that showed disconcerting tendencies to slide.

THREE MILLION YARDS of material per month are being pumped into the dam through numerous discharge pipes spotted at strategic points. The west-bank core pool is now rising above the sheetpile cutoff wall.



END of the shift. Part of the fleet of 70 fast trucks that one contractor is using to move 10,000,000 yd. from a spillway section.



DREDGE "Gallatin," one of four identical units built on the job by army engineers. Each dredge contains two 28-in. electrically driven pumps set in tandem.

from losses ordinarily experienced on this type of line, which usually makes up a greater portion of the pipe line of most dredges. The losses in the straight-flanged pipe are from 25 to 50 per cent less than the losses in the floating line. In laying out the Fort Peck dredging plan, care was taken to have as much of the total line as possible consist of long straight reaches of flanged pipe; therefore, the average head losses in the pipe lines have been considerably less than are usual on most dredging projects.

Discharge of fill material

Siamese connections at various points on the beaches and the light quick-connected ball and cone pipe lines provide great flexibility in the discharge-pipe layout. In general, lifts of 5 ft. are made on the beaches, a sand levee of this effective height being thrown up on the extreme outside line of the beaches by dragline before starting a new lift. At the first start of filling operations a levee was thrown up along the inside of the gravel toe to keep the silt material from sealing off the gravel and destroying its drainage properties.

The discharge of the pipe lines is usually caught on a wood-plank table, which serves to spread the flow and to prevent excessive erosion of the beach. If the discharge carries a high percentage of fine materials and a deficiency of heavier solids, it will wash through the beach sand in fairly deep channels. Ideal material, with the right mixture of solids, will build up around the discharge tables in a cone and will spread in a widening fan toward the core pool. When desired, the shape and extent of the discharge sheet flowing across the beaches can be controlled by batter boards, but they are used only part of the time, as excellent control can be secured by a slight shifting on the discharge pipes.

The downstream embankment is kept higher than that of the upstream side. The beaches have an average slope of 2 per cent, are remarkably solid and drain very fast; they resemble a hard-packed ocean beach, smooth and firm, and heavy equipment such as draglines and tractors drawing sleds loaded with pipe can move across freshly deposited fill and even through the discharge sheet without trouble.

Development of core pool

At the edge of the core pool, the solid sand beach gives way abruptly to the soft silt core. The core pool is held at 2- to 6-ft. depth at the center, the shallow depth being preferred. The shore lines of the pool are never allowed to come within the core limits as defined on the cross-section of the dam (Fig. 2); a leeway of 100 ft. in width is allowed at present outside the core limits. Also no attempt is made to keep the shore line parallel with the axis of the dam, which results in a varying width

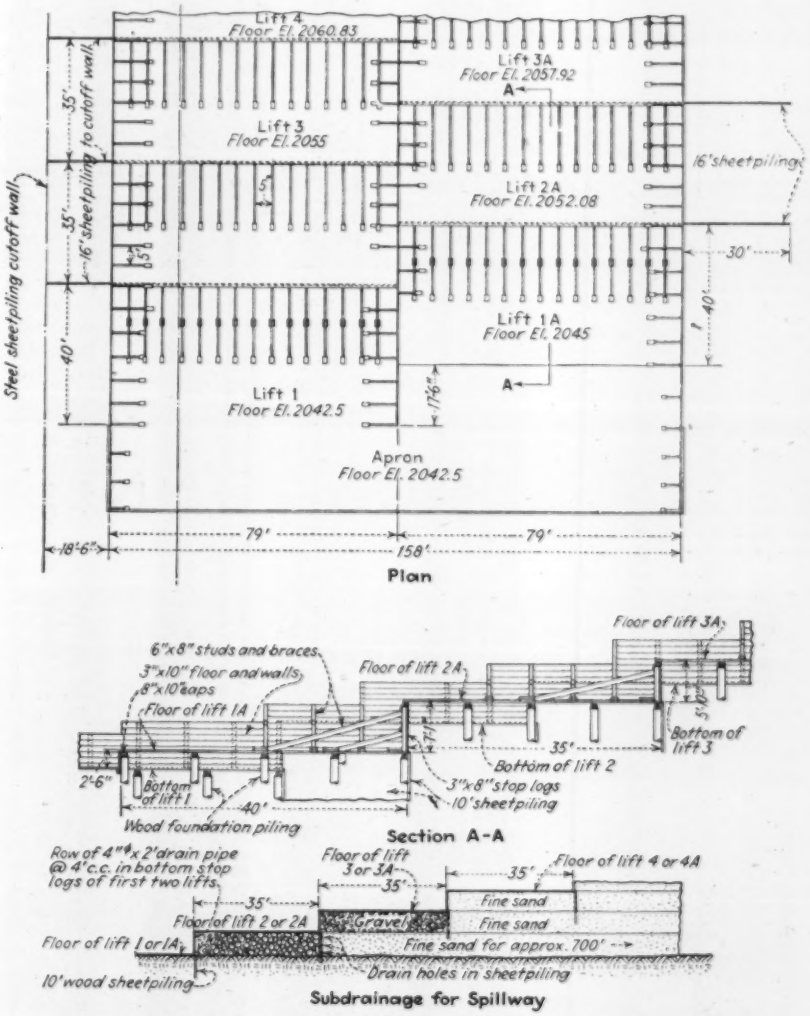


FIG. 16—SLUICEWAYS to regulate the depth of core pool and the flow of waste water are built into the sand dikes restraining the river ends of the silt cores.

of pool. General practice is to keep the pool wide for five or six days, then narrow it suddenly in an attempt to wash down the finer materials along the shore lines, to get a gradual and uniform distribution from coarse to fine materials along the core limits.

Waste from the pools and elevation of water level are controlled by two wooden sluiceways (Fig. 16) in the riverside ends of the cores, one on each side of the river. At first, when the pools were at low levels, split by the sheetpile diaphragm, temporary weirs were required on each side of the corewall. Slots were cut in the sheetpiling at varying intervals and elevations, to permit passage of the core-pool water and to prevent building up a hydraulic head on one side of the sheeting. Before this was done, the unbalanced head on a section of corewall caused a bad rupture in the piling.

Now that the cores are rising above the corewall, permanent sluiceways have been built on the center line of the cores, just downstream from the sheeting line. Each set of waste weirs consists of two adjacent sluiceways 79 ft. wide, staggered in lifts of slightly more than 5 ft. in height. They are carried on wood piling driven by a dragline rig. Wood caps across the tops of the piling carry the plank-floor system. As each lift is built up, a wood sheetpile cutoff wall provided with weep holes for drainage is driven across the upper end, to keep the core from slumping out beneath. The space under the floors is packed with sand, except that gravel was used for the two lowest lifts. Plank stoplogs placed across the upper ends of the sluiceway boxes regulate the height of pool.

Material for building up the sand dikes along the river banks is provided by the discharge pipe leading to the sluiceway areas. These lines are kept ready at all times to discharge material whenever required. They discharge on the core-pool side of the dikes and build up the dikes quickly, as the silt material is carried off rapidly by the steep inside slopes that are maintained. Draglines

and bulldozers aid in building up the sand dikes, which are very stable.

Waste and core

The amount of solids lost over the waste weirs, all very fine silt, varies from 2 to 6 per cent.

Tests show that the core is solidifying with a rapidity beyond expectations. A pointed bar shoved into the center of the core from a boat strikes resistance at 4 ft. below the top of the core and is stopped at 10 ft. This consolidation of the core is very encouraging, especially in view of the present method of construction of the dam with the sand dikes restraining the riverside core ends.

Filling progress

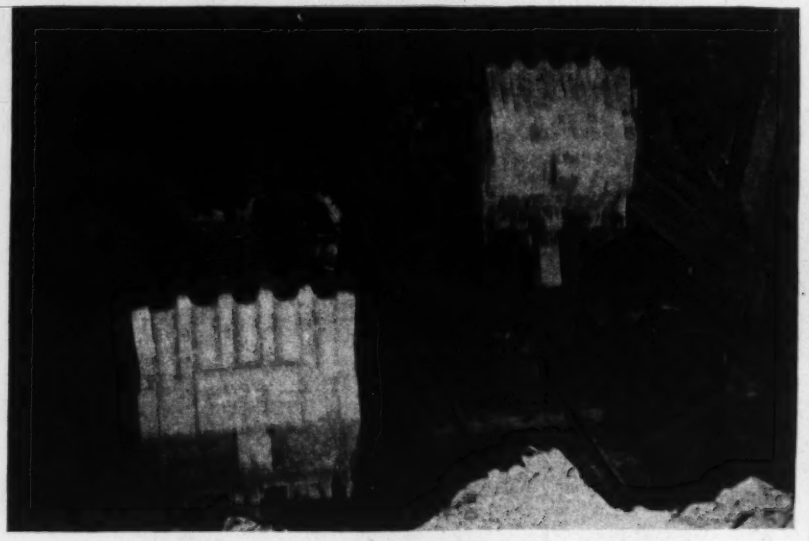
The plant was designed to place 3,000,000 cu.yd. of material per month and is now slightly exceeding that amount. By careful advance planning the shutdown of units due to pipe changes has been reduced to a minimum. A perfect day's run would be a total of 96 hours of pumping for all four dredges. A check-up of the period June 16-30 showed daily pumping totals from 75 to 90 hours. Daily averages of materials pumped per hour by each dredge vary from 1,200 to 1,900 cu.yd. The power requirement for all four pumping units averages 20,000,000 kw.-hr. per month.

Direction

Capt. D. A. Ogden is in direct charge of construction of the dam. Capt. C. N. Iry is in charge of the power and electrical distribution system, and Capt. C. H. Chorpening is in charge of gravel and stone toe filling and the sheet pile cutoff wall. C. S. Smith is superintendent of dredging and filling operations.

An article in a subsequent issue will describe the design of the dredges and pumping equipment in greater detail.

DIVERSION-TUNNEL DRIVING



A RARE SIGHT IN TUNNELING is this head-on view of two mucking machines working side by side loading out excavation from the enlarging operations.

Enlargement from Center Headings

Ring-drilling in advance from pilot tunnels—Steel beam ring supports set from moving platform jumbo—Twin muckers feed long loading belts—Large-diameter shafts underpinned by heavy steelwork

TUNNELING OPERATIONS for the four 32-ft. diversion bores that bypass the east end of Fort Peck Dam are at present in a state of change from pilot-tunnel driving to enlargement work. Enlarging the bores to full size in the treacherous blocky shale formation is a difficult and hazardous operation, requiring more than ordinary tunneling skill and equipment. Designs call for a unique lining of steel ring beams, purlins and 18-gage sheets and a 21-in. shell of concrete. Under a subsequent contract a steel-plate inner lining grouted in and a concrete inner protection coat for the steel will be placed, leaving a finished tunnel 26 ft. in diameter. The present contractor has developed a most unusual plant for the enlarging and lining work.

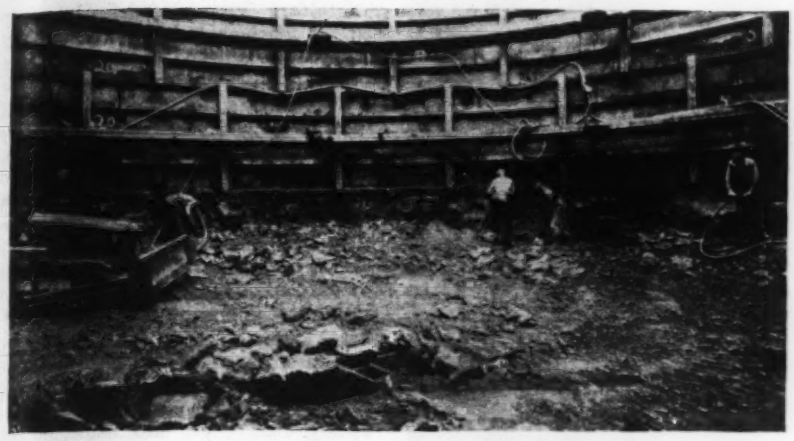
Design of the tunnels, totaling 4.8 miles in length, is described in the article on p. 284, and is shown in Fig. 3. Control works will be placed in four 50-ft. (finished diameter) shafts now being sunk to a depth of 240 ft. from the surface. These shafts, 60 ft. in rock diameter, are located near the axis of the dam. A 16x34-ft. shaft for emergency stoplog closure is being sunk immediately upstream from each control shaft.

The specifications called for driving a 16x14-ft. center pilot heading through the full length of each tunnel, lined with timber sets, before enlarging operations were started. Driven from the upper portals, all four pilot headings are now complete, and enlarging to full size is under way. Contrary to the pilot-tunnel procedure, the enlargement is being carried forward from the lower portals only.

Driving and enlarging difficulties are multiplied by the peculiar nature of the Bearpaw shale formation in which the tunnels lie. This is a fairly hard but much-faulted formation, blocky in structure and containing slippery seams of Bentonite, a compacted volcanic ash. Though impervious, the shale has a high moisture content, which escapes when the formation is exposed to air, resulting in very rapid disintegration. To check this disintegration, it is necessary to spray several coats of a bituminous sealing solution over the freshly exposed surfaces. Furthermore, the relative humidity within the tunnels is maintained at 90 by water-jet atomizers placed every 200 ft., consisting of a combination jet attached to the high-pressure air line and to the tunnel water line (125-lb. pressure).

Driving the pilot tunnels

Unusually fast progress was made in driving the small headings, a record of 1,608 ft. being made in one month in one of the bores. Driving was by conventional methods, except that 8-ft.-long auger bits were used for drilling the blasting holes. The full length of the work was timbered with posts and five-segment arches, lagged at the roof and kept



A BULLDOZER IN A HOLE is an odd sight at the bottom of one of the 60-ft. shafts. It shoves the broken-down shale from enlarging operations into the central glory-hole to waiting muck cars in the pilot tunnel below.

close to the face at all times. Mucking was by machine-loading onto a high conveyor belt arrangement that discharged directly into side-dump cars. Haulage was by trolley locomotives.

Elaborate belt-conveyor systems at each end of the tunnels provided a unique but efficient muck-disposal system. These conveyors handled not only the tunnel muck but disposed of large quantities of material excavated from the portal areas as well.

Details of driving the pilot tunnels, the muck-disposal system and concrete plant for the headwalls were described in *ENR*, May 23, 1935, p. 735.

Tunnel saw experiments

Mention was made in this previous article of experiments being conducted with a tunnel saw, modeled after a coal-mining saw. Two of these saws, cutting a kerf 4 in. wide and 9 ft. deep around the perimeter of the bore, were tried out in the pilot headings but proved unsatisfactory. Under different conditions they probably would have worked. One obstacle was the necessity of carrying the timber tight against the face, which cramped the working space for the supporting arm. Another difficulty was in holding the track upon which the saw rig operated. Then too, difficulty was encountered in falling blocks of shale at the crown. These troubles delayed operations considerably, largely nullifying the saving in time hoped for by the use of the saws. At that time it was intended to use the saws in enlargement work, but other means have been devised, which will be described later.

Enlarging the tunnels

Following completion of the pilot tunnels, the work of enlarging the tunnels has just begun. The pilot tunnels were all driven from the inlet ends, and enlarging is proceeding from the outlet end. The general methods of enlarging and lining can be given here, but at present the operations are in an experimental stage and in all probability will be changed in several respects. Not until some weeks more is the work expected to be ironed out to a routine basis.

The first step in the enlargement operations is the drilling. The ring-drilling method is used, 24 holes being drilled at 15-deg. intervals in a plane normal to the center line of each tunnel. Drilling is done from a 16-ft. longitudinal bar mounted on a rail carriage, the bar being adjustable for setting at the exact center line. Three or four drills are mounted on this bar at 3½-ft. or 7-ft. longitudinal spacing, depending upon the type of steel ribs to be used at a particular station, and three or four complete rings of holes are drilled from one set-up of the carriage. One ring at a time is blasted out, the excavation cleaned up and the rib steel set before another blast is fired.

Drill steels with chisel bits bore through the timber lining of the pilot bores, even through the track ties and on into the shale with ease. Drilling started in advance of other work and will be kept 800 to 1,000 ft. ahead of blasting.

Working jumbo

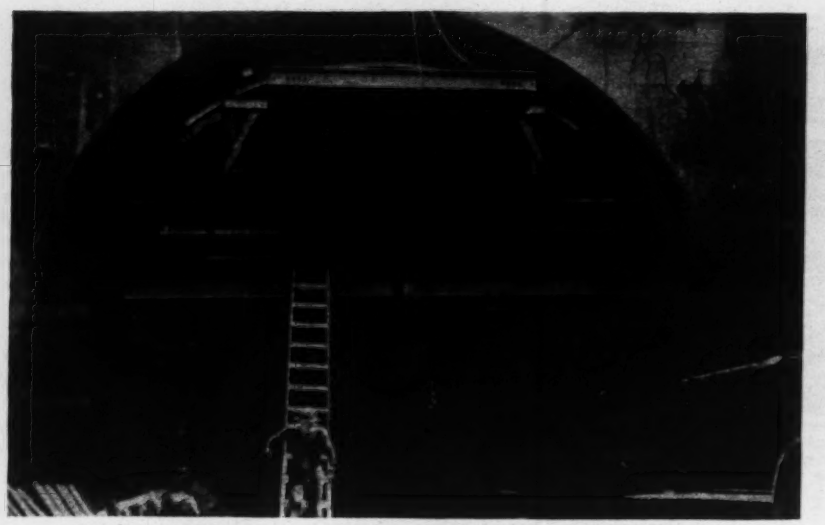
An ingenious traveling jumbo has been devised by the contractor as a working platform for trimming the bore to line after blasting and for erection of the steel rib supports. This jumbo is a steel framework 40 ft. long mounted on a wide-gage track and carrying three platforms, each of which rides on rollers over the steel framework, and can be independently extended 10 ft. beyond the jumbo frame. Air pistons provide the means of extending and retracting the platforms. From the extended platforms the newly blasted section of the enlarged tunnel is trimmed with pneumatic chisels, and the first coat of sealing compound is sprayed over the face of the freshly exposed shale.

At present the contractor is experimenting with various methods of channeling out the perimeter of the enlarged section prior to blasting. This would be extremely helpful in the bottom section, where trimming after blasting is laborious, as each chip of shale cut loose here must be lifted out of the way by hand.

If the roof of the enlarged section being worked on looks bad, crown bars of 6x6-in. timbers are inserted to provide immediate support. The bars are set over the top of the forward (last set) rib, the back ends being caught under the top flange of the adjacent ring of steel.

Straddling the top platform and car-

HEAVY steel framing for the shaft foundations is being erected in short sections within narrow working quarters. At the left is a longitudinal drift over the column line; center view is looking at the roof of a completed bay; at the right is a heavy kneebrace at the top of one of the higher bents.



REAR END of the ingenious sliding-platform jumbo devised for trimming the enlarged tunnel section and for erecting the steel-ring supports. Working platforms can be extended 10 ft. beyond the forward end of the jumbo frame.

ried on rails supported on the jumbo frame is a rib-erection gantry. The ribs are in five segments. The upper three segments are assembled in the open, outside the tunnels. When a rib is to be set, the gantry is pulled forward, and the steel ring is lifted to place by vertical jacks on the gantry. Erection of the two lower segments to complete the ring, purlins and sheets is done while the jacks hold the top segments rigidly in place.

In the meantime mucking out has been under way. Two mucking machines, working side by side, overcast onto their own belts, which discharge into long hoppers feeding two long overhead belt-conveyor systems, carried by another gantry frame riding the same rails as the working platform jumbo. These belts are set high enough to clear a train of muck cars. Two five-car trains are loaded simultaneously by these belts, a train of empties being shoved underneath and pulled slowly backward as the cars are filled. Chain hoists on the front end of the belt-conveyor gantry lift the inclined sections leading to the muckers, and the attached hoppers, out of the way when it is desired to move the mucking machines in the clear for blasting.

Because each mucking machine is working to one side of the center line, it is necessary to excavate the lower part of the invert by hand—a depth of about 14 in.

The contractor had to devise means of fastening in place the light steel sheets that envelop the rib purlins. Three lengths of sheets, one 22 ft. and two 15 ft., are required to reach from springline to springline. The 22-ft. length forms the top section. In a shop on the job both ends of the top sheet and the upper ends of the other two sheets are crimped and punched for bolt fastenings, to form a continuous sheet over the arch. The lower ends of the side sheets are also crimped to fit around the lower outside flanges of the springline purlins. From the jumbo platforms the top sheet is worked into place, and the side sheets are then attached by bolting through the crimped joints. A ⅜x1-in. punched bar on each side is used to form a clamp through which the bolts pass. There is some slack in the sheets, permitting the lower ends to be drawn down far enough to be snapped around the springline purlins. Spring steel clips, also made in the shop, are then driven over the purlin flanges to hold the sheets in place.

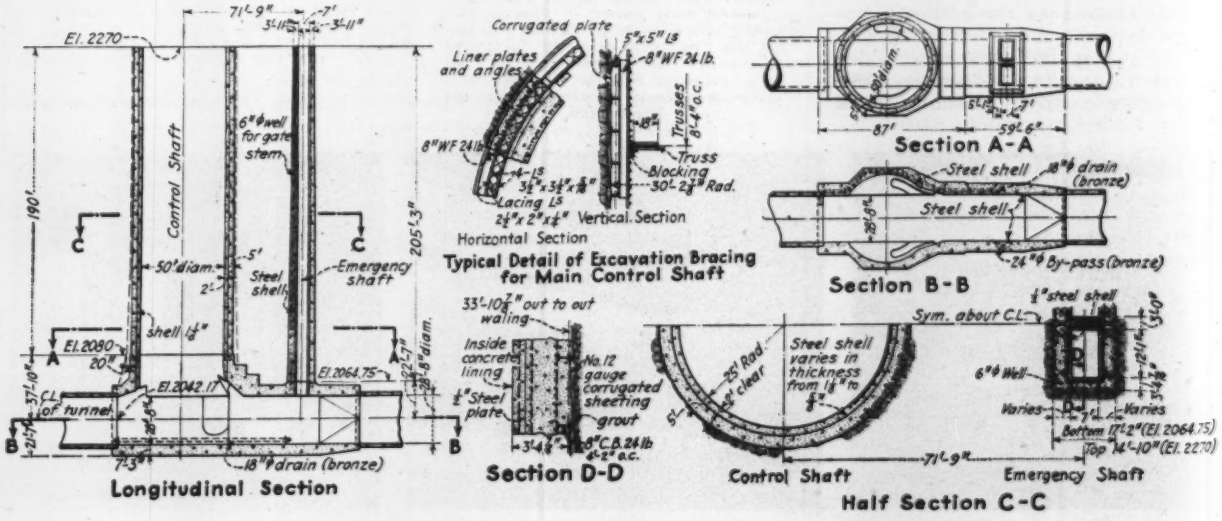
After the sheets are in place, the tunnel walls are sprayed twice more with the sealing compound. Whenever it is necessary to use crown bars, the steel sheets must necessarily be left out of that bent, as the bars block all access to the top part of the tunnel.

FIG. 17—EVEN MORE IMPRESSIVE than the tunnel lining (Fig. 3) is the lining of the 60-ft. control shafts. Details of this combination of steel sheets, vertical wales, truss ribs, steel-plate and reinforced-concrete structure are given here.

Concrete lining

Arrangements for placing the concrete tunnel lining still are in the preliminary stage. Plans are to pour a section of invert first, using 42-ft. steel forms, about 500 ft. behind enlargement excavation work. Invert concrete will be dumped into place from cars on tracks riding over the forms.

Following close behind the invert will be the wall and arch concreting, all placed in one monolith with 42-ft. lengths of steel forms. Concrete will be moved from cars to forms by twin pneumatic placing machines operating on tracks independent of the forms. The concrete guns will discharge through side spouts of adjustable length hanging down each side from the crown of the form. The entire assembly of guns, piping and spouts will slowly move back



and forth the full length of the forms while concrete is being placed to build up the side walls in uniform lifts. As the sides build up, the spouts will be shortened.

Shaft sinking

Sinking the four 60-ft. control shafts and the adjacent four emergency gate shafts is a major construction operation. In each of the eight shafts a small timber-lined pilot shaft was sunk to pilot-tunnel level, followed by enlarging to full size from the top. These pilot shafts were sunk with the use of paving breakers and pneumatic chisels, no drilling or blasting being required.

After the pilot shafts were sunk to tunnel level, they were fitted at the bottom with hoppers and gates for loading directly into muck cars on the pilot-tunnel tracks. In enlarging the shafts to full size, pneumatic tools again serve to break up the shale, and all muck is dumped down the pilot shafts which serve as glory-holes. The gates on the hoppers at the foot of each shaft are air-operated.

In the emergency-gate shafts, the muck from the enlargement is cast into the glory-hole by hand, but in the 60-ft. control shafts there is ample room in which to operate a tractor and bulldozer for shoving the loosened muck into the pilot shaft.

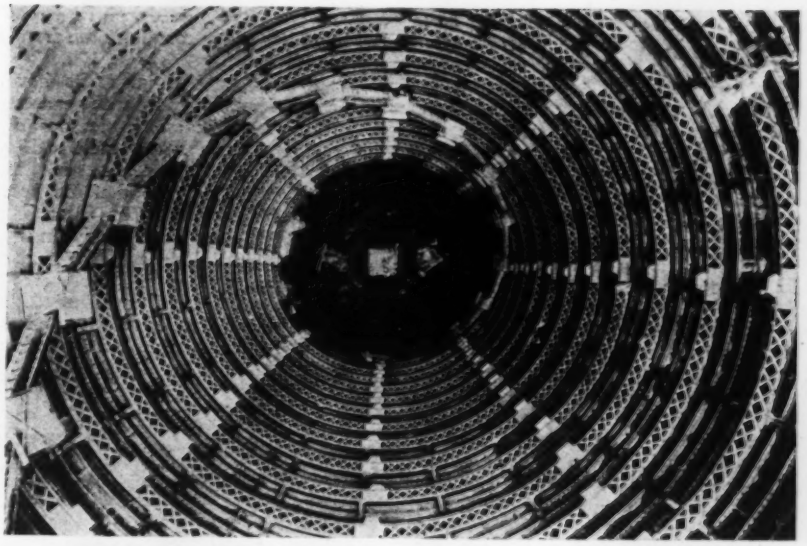
Control-shaft lining

The lining of the 60-ft. shafts is most unusual for a structure of this type, and when finally completed will total 5 ft. in thickness. As the enlargement excavation is carried downward, corrugated steel plates, braced by double-angle rings, spaced 2 ft. apart, are set up on a 30-ft. radius. Bearing against the inner legs of the ring angles are 8-in. steel wales set in vertical position, which, in turn, are braced by horizontal steel truss rings, 18 in. wide, spaced 8 ft. 4 in. apart vertically (Fig. 17). All of this forms the ground support of the sinking operations. Grout is pumped as quickly as possible behind the corrugated plates to provide uniform bearing against the rock.

The remainder of the lining, which will be placed after sinking is completed, consists of a 3-ft. reinforced-concrete shell, inside of which will be built a steel-plate lining, from $\frac{5}{8}$ to $1\frac{1}{8}$ in. thick, all welded joints. As a protection to the steel shell an inner lining of heavily reinforced concrete will be placed.

Inside the structural lining the control works, with riser shafts, etc., will be erected, details of which have not as yet been definitely worked out.

All of the joints in the steel shell lining will be butt-welded, stiffened with 4x4x$\frac{1}{2}$-in. angles, continuously welded. The steel shell must necessarily be erected prior to placing the outer concrete lining, to allow welders to work behind the shell. Literally miles of arc welds will be required. As yet details of the field welding are incomplete.

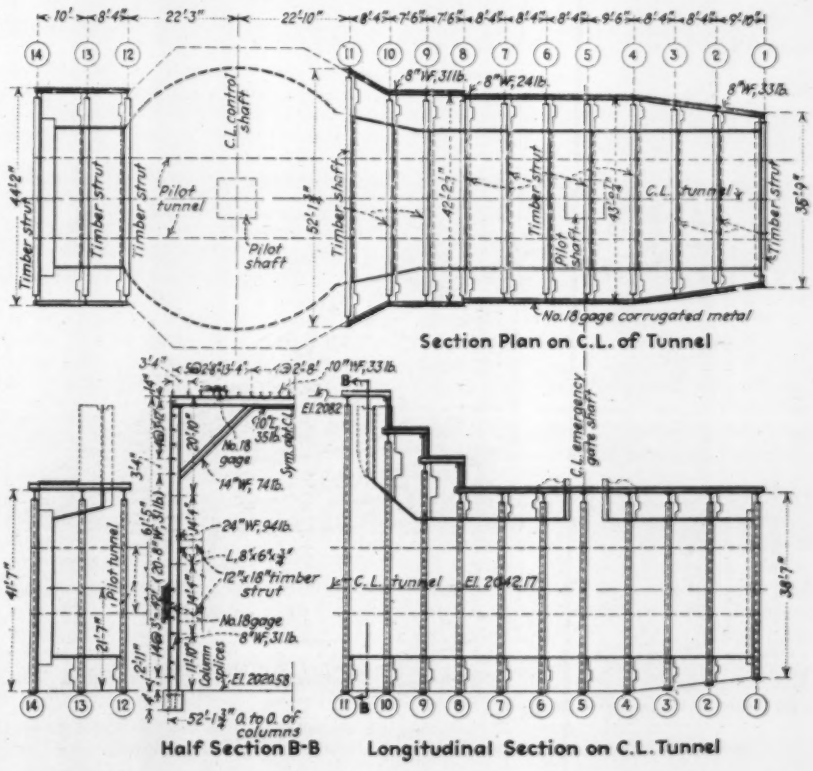


STEEL RING TRUSSES, backed by vertical wales and steel-plate lining, support the ground in the 60-ft. control shafts being sunk 240 ft. through shale and overburden.

Some means must be provided to support the tremendous load of the shaft lining over the tunnel section. This problem has been met by a design of steel-frame transverse bents, fourteen in each tunnel, with the posts carried below invert level of the completed tunnel.

The bents extend from the upstream side of the emergency-gate shafts to beyond the downstream side of the control shafts, as shown in Fig. 18. The framing of each bent consists of 24-in. wide-flange columns and top girders, with 8-in. side purlins and 10-in. roof beams spanning between bents. En-

FIG. 18—STEEL-FRAME BENTS will support the heavy loads of the shaft lining. This steelwork is being erected in short sections from raises and drifts carried from the pilot tunnels while sinking of the enlarged shafts waits 100 ft. overhead.



veloping the sides and top of the steel framing is a cover of 18-gage steel sheeting. The bents vary from 35 ft. 9 in. wide and 38 ft. 7 in. high to 52 ft. 7 in. wide and 62 ft. 3 in. high. On the higher bents 14-in. kneebraces are required.

Erection of the steel bents is one of the most difficult and tedious parts of the tunneling operations. Enlargement of the shafts has been stopped from 80 to 100 ft. from the bottom until the foundation steel can be installed. This step is believed necessary to avoid disturbing the surrounding shale at the bottom of each shaft in event of a cave-in as the shaft excavation nears bottom.

The first operation in steel erection is to raise a cross-drift between bents 7 and 8 (Fig. 18) from the pilot tunnel to top of the proposed steel, the drift extending both ways to the column line. Heavy timber bracing is required for this work, and the customary spraying of the exposed shale with bitumen follows immediately behind excavation. When the drift is finished, the four columns for bents 7 and 8 are placed in shafts sunk to future tunnel-invert level from the drift. Next, the transverse roof girders are erected in short sections with full-strength field splices. Placing of the kneebraces, purlins, roof beams and sheeting completes the framing for one bay.

Meanwhile, longitudinal drifts have been carried both ways from the ends of the first cross-drift along the tops of the column lines. From these drifts shafts for the columns are sunk to grade. Then widening out of the first transverse drift begins, taking in an additional bay on each side. Timbering is placed, removed and placed again in the process of excavation and steel erection. The steel is bulled into place with the aid of air hoists, chain hoists, jacks, brute strength and considerable profanity.

Headwall construction

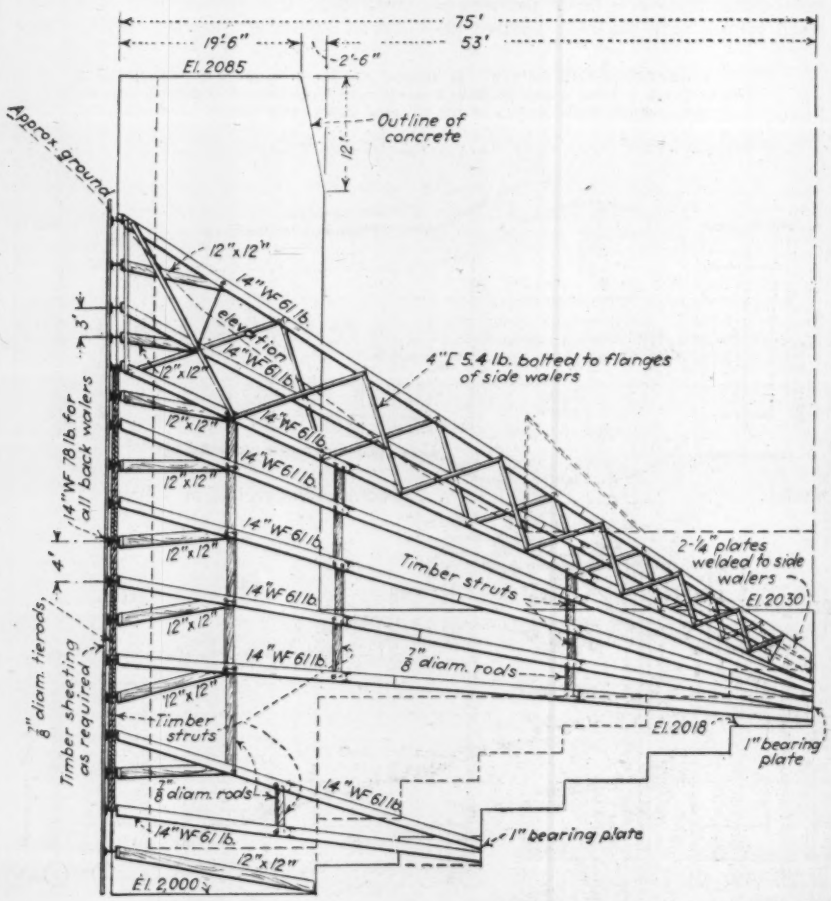
The headwall and retaining walls at the outlet portals are complete. At the inlet portals excavation is now under way for the headwalls, and a concrete plant is about ready for operation. Concrete will be placed by a duplex pumping rig, which was previously used to some extent on the lower headwalls.

The inlet headwall is being placed in two 21-ft. and one 50-ft. section between tunnel openings. The procedure is first to excavate and concrete the 21-ft. sections on either side of the tunnel openings, then follow with the 50-ft. sections to close the gaps. Heavy steel-beam bracing is required to hold the ground, the steel wales and posts being supported by temporary raker beams, as shown in Fig. 19.

Direction

The tunnels are under the supervision of Capt. A. W. Pence. The Mason & Walsh Co. is contractor, with W. A. Durkin as superintendent.

FIG. 19—HEADWALLS for the upstream portals are being built in short sections requiring heavy steel and timber bracing to hold the shale banks in place while the massive walls are being poured.



PRINCIPAL CONSTRUCTION CONTRACTS AT FORT PECK

CORE DRILLING
Longyear Exploration Co., Minneapolis, $54,285.
S. J. Mathews, Tulsa, Okla., $37,179.
Mott Core Drilling Co., Huntington, W. Va., $23,269.
Diamond Drill Contr. Co., Spokane, $103,516.

MILK RIVER RAILROAD BRIDGE
Minneapolis Bridge Co., Minneapolis, $59,674.

GAS-DISTRIBUTION SYSTEM
Municipal Service Co., Kansas City, $43,840.

MISSOURI RIVER BRIDGE
Massman Const. Co., Kansas City, $984,772.

SUBSTATIONS AND BUILDINGS
Westinghouse Elec. Co., Pittsburgh, $529,473.
Allis Chalmers Mfg. Co., Milwaukee, $203,000.
W. C. Smith, Inc., Duluth, $18,632.

ELECTRIC DISTRIBUTION SYSTEM
P. O. Montgomery Co., Dallas, $79,429.

ELECTRIC TRANSMISSION LINE
Ziebarth & Walker, Los Angeles, $1,070,500.

STREETS & ROADS (town)
Morrison-Knudsen Co., Spokane, $246,951.

CAMP AND TOWN BUILDINGS
Madsen Const. Co., Minneapolis, $1,453,795.
Johnson, Drake & Piper, Inc., Minneapolis, $740,212.
C. F. Haglin Co., Minneapolis, $732,243.

SEWERAGE AND WATER SYSTEM
C. F. Lytle, Sioux City, Ia., $224,013.

WATER-FILTRATION PLANT
Gjellfald Const. Co., Forest City, Ia., $162,858.

DIVERSION TUNNELS
Mason & Walsh Co., New York, $7,311,940.

TRESTLES
Addison Miller, Inc., St. Paul, $349,933.
Morrison-Glasscock-Connor Co., Kansas City, $143,719.

STRIPPING DAM SITE
Addison Miller, Inc., St. Paul, $1,292,320.

ELECTRIC FEEDERS TO DREDGES AND TUNNELS
A. S. Schulman Co., Chicago, $398,610.

STEEL-PILE CUTOFF WALL
Frazier-Davis Const. Co., St. Louis, $2,157,840.

SPILLWAY AND STRUCTURES
Martin Wunderlich, Jefferson City, Mo., $1,168,120.
Spillway Builders, Inc., Kansas City, $7,133,005.
Addison Miller, Inc., & Fielding & Shepley, St. Paul, $3,985,423.

GRAVEL FOR TOE FILLS
J. L. Shiely & Becker County Sand & Gravel Co., $1,560,000

CONCRETE AGGREGATES
J. L. Shiely, St. Paul, $286,000.

GATHERING FIELD BOULDERS
Tobin Quarries, Inc., Kansas City, $431,250.
R. Newton McDowell Inc., Kansas City, $368,000.

LOADING OUT FIELD BOULDERS
Tomlinson-Arkwright Co., Great Falls, $120,000.

BY GOVERNMENT DAY LABOR
Building the dam (hydraulic fill).
Gravel toes.
Rock toes and blanket.
Wiota-Ft. Peck railroad.
Clearing and grubbing dam site.
Construction of almost all floating plant, including dredges.
Temporary buildings.
Temporary water supply, electric-distribution systems.

SPILLWAY CUT AND STRUCTURES

TEN-SECOND DUMPING is the rule here, where 40,000 cu.yd. of shale from a section of the spillway cut are deposited daily. The well-maintained broad surface of the dump allows quick maneuvering of the trucks to unloading position.

Excavation Methods and Equipment

Shovels and truck fleets moving 13,000,000 cu.yd. from two-mile cut under two contracts—40,000 cu.yd. per day average for one section—Complete equipment service facilities required

SLASHING their way through the Missouri River breaks 3½ miles east of the Fort Peck Dam, two contractors are removing at remarkably fast pace a volume of 13,000,000 cu.yd. of shale and overburden from the spillway cut, or no less than 6½ million yd. of excavation per mile. With a fleet of 96 trucks, 70 of them high-speed units, nine shovels and a dragline, one contractor is attacking his 10,000,000-yd. job at the rate of 40,000 yd. per day. The other contractor, removing 2,800,000 cu.yd. at the lower end of the two-mile cut, is handling about 10,000 yd. a day with four shovels and 22 hauling units. Both jobs represent well-planned, smoothly working dirt-moving operations with modern motor haulage.

The design of the huge spillway cut (Fig. 4) is described in the article on p. 284. From 4,536 lin.-ft. of test borings in 74 holes, it was determined that the same Bearpaw shale that is found under the dam underlies the spillway. It is covered by 10 to 70 ft. of disintegrated shale overburden. The maximum depth of cut is 190 ft. Through the overburden, side slopes are carried at 1 on 3; in the shale they are made 1 on 2. To expedite excavation, the government started the cut by removing 550,000 cu.yd. in one month with rented equipment. This was done in a period of delay in awarding the two excavation contracts, principally to keep a large crew of men at work until the contractors could take care of them.

The excavation was divided into four priorities, of which Martin Wunderlich was awarded one at the outlet end, and the Spillway Builders, Inc. (originally the Massman Construction Co.) was awarded the three others. The latter contract includes all of the channel paving and lining, but the gate and cutoff structures are under a subsequent contract.

To clear the way for construction of the huge gate structure, Spillway Builders was required under its contract to concentrate at first on the approach channel section and finish this part of the work before starting the remainder. This resulted in splitting the work, really making two separate jobs of it, and necessitated a different attack from that of a single job for the entire length of the contract. Excavation for this first section was moved to upstream spoil banks. All of the extensive shop and servicing equipment had to be moved when the approach work was finished. A total of 4,200,000 cu.yd. was taken out of the gate and approach area on a haul averaging from 1 to 1.6 miles.

Spillway Builders' contract

The methods and equipment used by Spillway Builders will be described first, followed by that of the Wunderlich job, where somewhat different methods are in use.

The Spillway Builders contract schedule calls for excavating the first 7,200,000 cu.yd. in 300 calendar days, an average of 28,570 cu.yd. per day. At present the rate of operations is close to 1,000,000 cu.yd. per month on a six-day week, three 6½-hour shifts per day. The daily average is 40,000 cu.yd., and 46,754 cu.yd. was the best day's run.

To meet his schedule, the contractor decided upon fast but rugged equipment, purchasing seventy 6-yd. dump trucks to haul 8 yd. of loose material. These trucks operate from 25 to 30 miles per hour up and down grade between shovel and dumps. Nine new 2-yd. diesel-powered shovels were chosen for the digging equipment, this size unit being considered the most economical as four passes of a shovel fill a truck. A diesel 1½-yd. dragline trims the slopes and assists in building the roads. A fleet of ten diesel tractors, seven equipped with bulldozers, and two patrol road graders complete the heavy equipment.

During the approach channel work, three 1½-yd. gas shovels and 26 8-yd. trucks of slower speed than the new ones were rented and added to the equipment. With this augmented plant 1,500,000 cu.yd. were moved in April and 1,300,000 in May. Now that the first section is finished, the extra shovels have been discarded, but the trucks are still in use, making a fleet of 96 trucks serving nine shovels.

While the spillway cut follows a natural flowage way through the breaks, the site abounds in hills and coulees. The first operation is to flatten out the hills to work down to as long straight runs of the shovels as possible. Starting with a bulldozer and following with a shovel, a spiral road is cut around the hills to be attacked, providing access to the top. Once a straight-line operation has been worked, it continues down through the channel, with shovel cuts running parallel to the center line of the spillway in lengths up to 1,500 ft. The excavation proceeds in benches 10 to 12 ft. high, generally worked from the sides of the cut toward the center. Surprising as it may seem, the shale digs easier than the hard-packed overburden.

Each shovel cut is carefully planned in advance. This requires not only a consideration of the movements of the shovel through the area but a planning of access roads as well. Colored pins on a map in the superintendent's office indicate the location of every shovel at all times, and the access roads are sketched in when necessary to work out a new system of truck routes.

The number of trucks assigned to a shovel varies from day to day, depending upon the nature of material being excavated, the length of haul from a particular shovel and other conditions. On the side of the repair shop are three huge blackboards, one for each shift. Each truck is numbered, and prior to every shift the shovel to which each truck is assigned is marked upon the board, along with the badge number of the driver. Every truck is accounted for; those in the shop, or in bad order, or laid off for any reason, are so marked upon the board.

Once assigned to a certain shovel the trucks stay with that unit for the duration of the shift. However, the shift foreman may change the truck assignments as conditions may warrant. Usually from nine to fourteen trucks are allotted to one shovel. Operations are so carefully scheduled that seldom does a shovel stop for lack of a truck, and rarely is there more than one empty truck at a shovel waiting to be loaded.

Working out the shovel cuts is but one item in keeping the operations going smoothly. Just as important is the building of roads to the dumps and careful maintenance of the spoil banks. The dumps are maintained in excellent condition, with broad dumping surfaces permitting fast maneuvering to an unloading position.

Usually two dumps are in use, trucks from certain shovels being assigned to each dump. From the shovels, the trucks take definite roads and definite lanes on the wider roads. Returning, they take different lanes and routes. Adherence to the assigned route is most rigidly enforced upon the truck drivers, for any departure would be hazardous because of the high speeds of travel. The main roads and the dumps are well lighted at night with a standard street-lighting system. Constant sprinkling of the roads keeps down the dust to some extent and reduces accident hazards.

Servicing the equipment

Operating the large fleet of equipment a thousand miles from the nearest factory service plant necessitates most elaborate service facilities. A splendidly equipped repair shop and well-stocked storeroom are maintained. Even major repairs are possible on the job, such as welding broken shovel axles or complete rebuilding of a truck if necessary.

Servicing of the trucks is a revelation in efficiency. Five gasoline stations set in a row are fed by gravity from storage tanks on a near-by hill. Some of the trucks are painted red, others white. At a certain time a white flag is displayed along the road to the dump. At once the white-painted trucks flock to the gas station on the return trip, five at a time. If the filling stations are full, a truck doesn't stand in line waiting but returns for a load and stops at the gasoline station on the next trip. When

OVER THE END of the dump come 8 yd. of blocky shale from the lower end of the spillway cut. Few seconds are lost in dumping these trucks.

all of the white trucks are filled up, a red flag is displayed and the filling process is repeated for the red-painted trucks. Trucks are filled in less than 1 min. each.

Each truck is serviced, greased and oiled once a day on the daylight shift, on one of two grease racks. Each is assigned to a definite time for greasing, and in 5 min. the crankcase oil is changed, the chassis is greased, the cylinder oil in the body hoists is checked, and the tires are inspected. A tire showing any signs of failure is replaced during greasing operations. All used crankcase oil is run through centrifugal filters, and 90 per cent of it is reclaimed. Despite exceedingly dusty conditions, frequent changes of oil and the use of efficient air filters have kept all equipment free of burned-out bearings.

Shovels are serviced and inspected in the hour layoff between shifts. When major repairs to a shovel are required, it is brought to the shops and is torn down in a gantry-crane shed.

The contractors on the spillway have jointly built and maintained six miles of gravel road from the dam to the spillway, and have built a three-mile water line to the job. Water is supplied from the government water system through booster pumps, and is stored in a steel tank on a high point adjacent to the work.

Wunderlich's job

On the Martin Wunderlich contract, where 2,800,000 cu.yd. are being moved from the lower end of the spillway, operations are just as smooth but are rather less rushed than those on the upper portion. With four 1½-yd. diesel shovels and 22 hauling units, an average of 4,100 cu.yd. is handled each 6½-hour shift.

Having a smaller total yardage and a correspondingly smaller daily schedule, this contractor chose slower-speed hauling equipment than that used on the other contract. For the early part of the work, when the haul was fairly short, he used a fleet of 12 yd. crawler and pneumatic wheel wagons in trailer units of three pulled by a diesel tractor. As the haul became longer, he switched to eleven 8-yd. trucks and eleven 8-yd. tractor-truck wagon trailers, which run from 15 to 18 m.p.h. Usually 20 units are at work, five assigned to each shovel, and two are kept in reserve.

The same careful planning of shovel cuts as on the upper work is evident, the operations being laid out in practically the same manner in straight runs up to 1,000 ft. long. Hills are shaved down at first to provide the long shovel runs, kept parallel to the center line of the spillway. Cuts average 10 to 12 ft. deep and 20 to 25 ft. wide. Access roads and the roads to the dumps are built and maintained by bulldozers and road graders.

This end of the spillway is in a harder shale formation, requiring extensive blasting. To work the drilling and blasting in with the excavation schedules requires a delicate balancing of operations to keep from getting the whole works fouled. The shooting schedules vary greatly, partly due to ground conditions, but more because of the changing layout of the excavation work. Drilling crews work far in advance of excavation but shift around to keep out of the truck runways.

Holes are drilled vertically downward with hand pneumatic drills, the spacing both ways being equal to the depth of hole. Except along the side slopes, where the hole may be as shallow as 3 ft., the depth of drilling is usually 9 to 10 ft. An average day's run is 244 holes over an area of 100x200 ft. An average loading per hole is 4¾ lb. of 30 per cent straight gelatin.

Two portable 450-ft. gasoline compressors supply the air required for nine drills. Fishtail bits work best in the shale. Drill steels are available in various lengths from 2 to 10 ft., some drill runners preferring to start with a long steel, which requires a fewer number of changes. All bits are hand-sharpened and last about a week between sharpenings.

Side slopes on this contract are trimmed with a scraper pulled by a tractor. The rig starts at the top and travels down the slope perpendicular to the center line of spillway. This requires a long back trip to negotiate the steep slope, but the time required to trim to the desired grade is remarkably short. Rough sloping is done by the shovels as they work the outside cuts.

Winter work

Both contracts were begun late last fall, and work continued through the winter in the overburden excavation. Snow and extreme cold slowed up operations at times but never shut them down. Thousands of gallons of alcohol

were required for the truck radiators. In cold weather the truck engines were never stopped because of the difficulty in starting. Winter work was possible because several years of drought had lowered the groundwater level and the moisture content of the soil to such an extent that the ground did not freeze solidly. Some blasting was required to break up occasional patches of frozen ground. This spring and summer have seen considerable rain, which raises havoc with the shale roads and dumps. Chains are often required, and on the tractor truck units detachable lugs or grousers help negotiate the slippery roads.

Direction

Capt. John R. Hardin is in charge of spillway operations. W. J. Foster is superintendent for the Martin Wunderlich Co., of Jefferson City, Mo. For Spillway Builders, Inc., of Kansas City, A. D. Harvey is superintendent.

Concrete Structures for Spillway

Control-gate works, channel lining and deep cellular cutoff walls require half a million yards of concrete—Gate structure is founded on 520 concrete cylinders—Extensive system of tiles underdrains the channel lining

SEVERAL unique and interesting concrete structures form part of the spillway system to control and pass 254,000 sec.-ft. of overflow through the two-mile trough dug out of the bluffs of unstable shale overlooking the Missouri River at Fort Peck. The general features of this spillway are described in the article on p. 284.

Waste water from the vast reservoir will pass through a concrete gate structure near the inlet end of the spillway cut into a mile-long concrete-lined channel. Stoney gates will control the flow into the channel. Not far below the gates the lined channel, on a steep grade, narrows to a 130-ft. width. At the end of their mile-long rush through the lined section, the waste waters will reach the extraordinary velocity of 94 ft. per sec. At the end of the lined section a peculiar cellular concrete cutoff wall, extending 130 ft. deep into shale, is to be installed to prevent undercutting of the lined channel by back scour.

The gate structure

The spillway gate structure consists of seventeen piers set on a curved line, between which are suspended the sixteen 40x26-ft. Stoney gates, with provision for emergency stoplog closure. Fifteen of these piers extend about 200 ft. downstream, to form training walls for the discharge water. Surmounting the piers are a service railroad bridge, from which the gates will be handled, and a highway bridge.

The approach channel to the gate structure, 820 ft. wide, will be paved with a 3-ft. slab for 220 ft. upstream, protected by a strip of riprap for another 100 ft. above the paving. The seventeen piers rest on a solid concrete slab 80 ft. wide and 12½ ft. thick, founded on 520 concrete cylinders, 5 and 6 ft. in diameter, sunk 35 to 40 ft. into the shale. This foundation will carry the gate structure, even though the supporting slab should be undermined.

Holes for the cylinders will be bored by a special auger drill driven by an electric motor, the drill and motor being hung from a line on a high-boom crane. A pipe strut from the rotor assembly to a corner of the crane boom provides the required torque resistance. At the time of this writing, experiments are being conducted to determine the proper pitch of auger blades for best results. Previous experiments with a 3-ft. bit demonstrated the feasibility of the apparatus.

Features of the design of the gate structure are shown in Fig. 20.

Cutoff wall

To resist scouring action at the lower end of the lined channel section of the spillway, where discharge velocities are high, a unique cutoff wall will be provided. Here the lined channel has a bottom width of 130 ft., a top width of 182 ft. and a depth of 60 ft.

Directly under the channel section the cutoff consists of a reinforced-concrete box 100x189 ft. in plan (Fig. 21) and 70 ft. deep under the channel floor. This box, its walls 8 ft. thick, is braced by six 8-ft. cross-walls, dividing the interior into seven cells. Flanking the ends of the central box are wing walls of the same cellular construction, 70½ ft. wide, with downstream walls 290 ft. long; extending to the top of the channel, they have a maximum depth of 130 ft.

The central box is covered with a 4-ft. concrete slab forming the floor of the channel; the wing walls are covered with concrete paving on earth backfill.

The contractor is contemplating using some kind of a saw rig for channeling out the excavation for the deep wall sections. Construction of the cutoff wall will not be undertaken until next year, after excavation of the spillway cut shall have been completed.

The quantities involved in the gate and cutoff wall structures are of very great size. Principal items are: excavation, 643,000 cu.yd.; rotary drill holes, 5 and 6 ft. in diameter, 18,700 lin.-ft.; steel sealing strips for construction joints, 231,000 lb.; concrete, 289,000 cu.yd.; steel gates, 2,120,000 lb.; temporary steel bracing, 1,000,000 lb.; permanent steel bracing, 2,500,000 lb.; miscellaneous metal, 2,395,000 lb.; reinforcing bars, 22,336,000 lb.; electrical conduit, 32,200 lin.-ft.; railroad, 9,200 ft.; and pavement, 36,500 sq.yd.

In the mile length between the gates and cutoff wall, the spillway channel will be lined with concrete on the floor

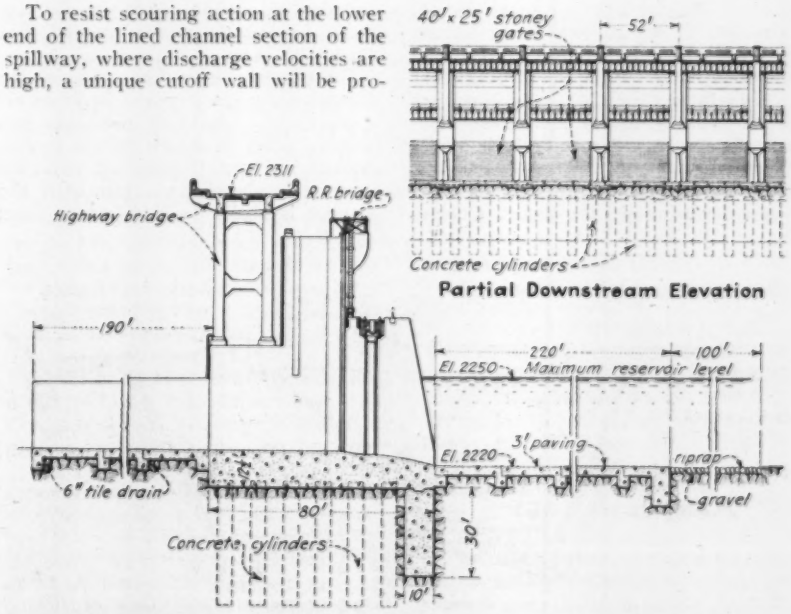


FIG. 20—FLOODFLOWS up to 254,000 sec.-ft. will pass into the spillway through this control-gate structure. A feature of the design is the foundation of 520 concrete cylinders carried 35 to 40 ft. into the shale.

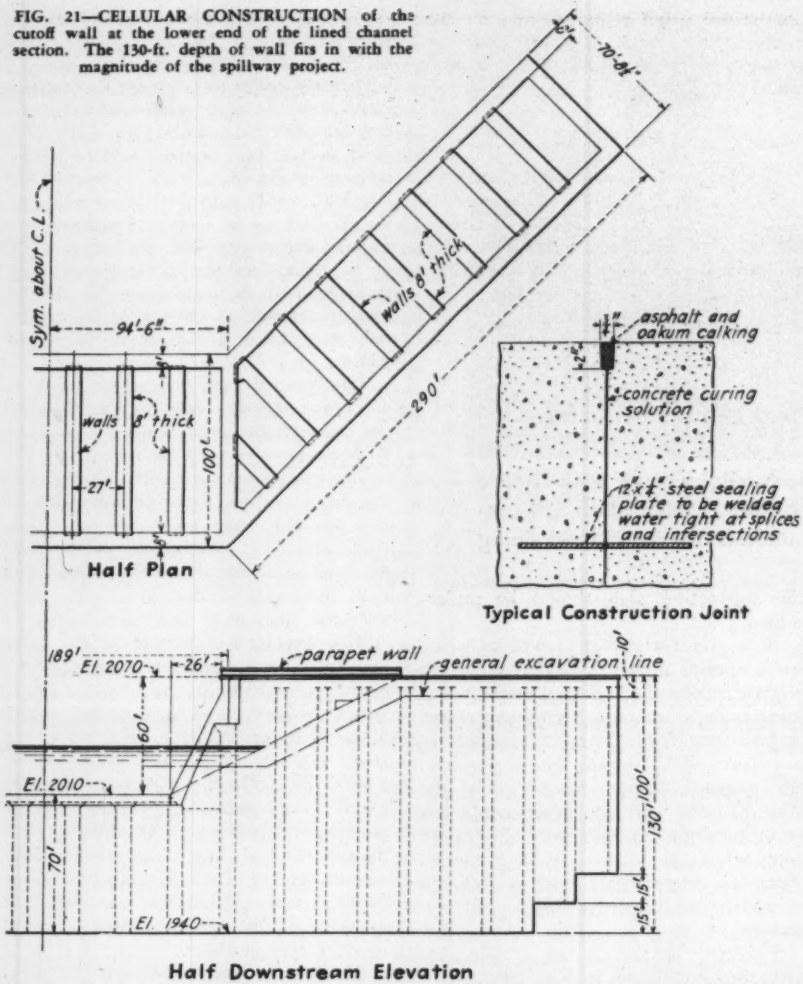


FIG. 21—CELLULAR CONSTRUCTION of the cutoff wall at the lower end of the lined channel section. The 130-ft. depth of wall fits in with the magnitude of the spillway project.

and walls. In this stretch the spillway channel is defined by a central trough, from 130 to 800 ft. wide at the bottom and averaging 30 ft. deep, with side slopes 2 on 1. It is this trough that is to be lined (Fig. 22). A bituminous paved berm flanks the tops of the channel. At the junction of the side slopes of the big cut and the paved berm is a concrete-lined drainage ditch to catch water coming down the slopes. Coulees draining into the spillway are to be protected by paving of precast concrete blocks (3x3x1 ft.) at the junction with the paved berm.

The Bearpaw shale through which the channel is cut disintegrates badly in air or in water. Therefore elaborate precautions must be taken after a face is exposed, to keep it protected until the concrete is placed, and again after the channel is lined, to keep water from collecting beneath the concrete sla... The first requirement will be met ... spraying the faces of the freshly exc... vated shale with a bituminous co... pound as soon as exposed; the seco... by installation of a vast network ... vitrified drain tile set in gravel.

The floor slabs, in general, will co... sist of 20x40-ft. blocks 28 in. thic..., heavily reinforced, and deepening to 3... in. thickness in the 18-ft. width ne... to the side walls. A system of ⅛x12-in. steel sealing strips, welded at all joints, will be installed in all construction joints between floor blocks. In addition to the steel strips, the floor joints will be calked with oakum and asphalt for a depth of 2 in. in ¾-in. calking grooves cast in the blocks. Every 120 ft. a transverse concrete cutoff wall will be carried to a depth of 5 ft. below bottom of slab. A total of 249,100 cu.yd. of concrete will be required for the channel lining.

Drainage system

Deep under the center line of the channel will be an 18-in. vitrified-tile line set in gravel, forming the backbone of the extensive drainage system. Smaller drain lines are laid under every construction joint in the floor and extend up the sides behind the walls and across the berm to the drainage ditch. The entire system is vented through vent pipes connected to the wall lines.

Except for the 18-in. trunk line, all longitudinal lines are 6-in. tile. Transverse lines alternate in 6-in. and 8-in. sizes. All tile are laid in gravel with uncalked joints.

The installation of the miles of tile drain pipe required will be an interesting but troublesome operation. A trench for every foot of the drain lines must be excavated or channeled out of the shale rock to careful line and grade, and the trench sides and bottom will have to be protected by the customary bituminous sealing solution. Extensive hand work will be necessary to prepare the gravel bed, to provide a smooth base for the tile, to lay the pipe and to place and smooth up the gravel covering over the pipe after it is laid.

Work started

Construction of the gate structure has been started by Addison Miller and Fielding & Shepley, of St. Paul, under the supervision of H. C. James. This firm also holds the contract for the cutoff wall. Spillway Builders, Inc., Kansas City, for whom A. D. Harvey is superintendent, expects to start the channel lining late this fall, though details of handling the concrete have not yet been worked out. The channel lining is part of this firm's extensive contract for spillway excavation. Lieut. John B. Fleming is in charge for the government on all concrete work in the spillway.

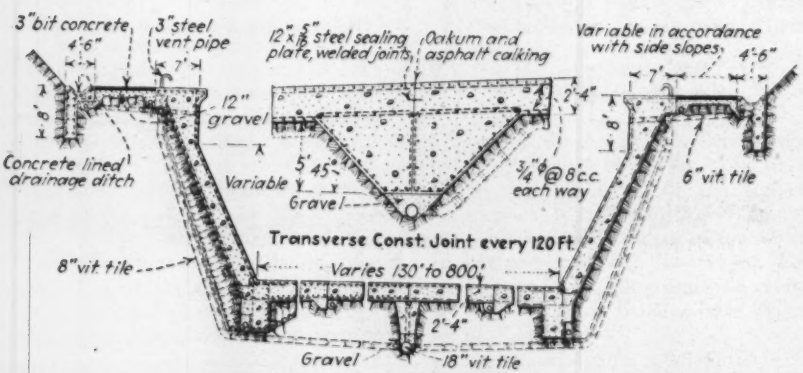
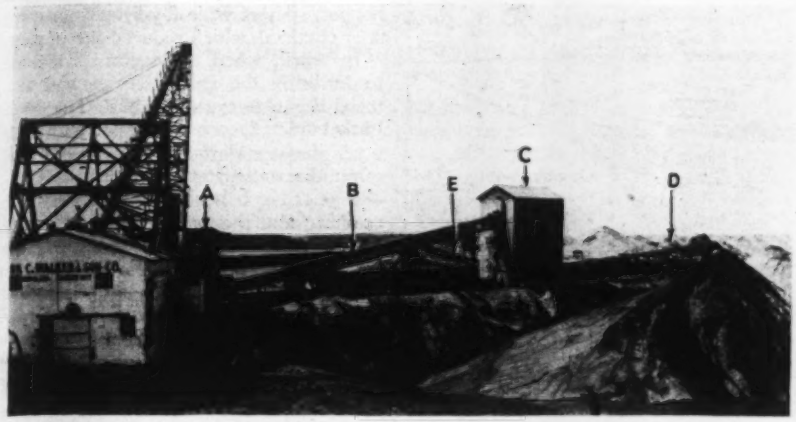


FIG. 22—CHANNEL LINING will consist of 20x40-ft. floor slabs 28 in. thick underlain with a network of tile drain pipes, and heavy side walls with a paved berm protection. Continuous steel joint strips and calked joints will make the floors and walls watertight.

SAND AND GRAVEL PRODUCTION



FED BY THE 8-YD. WALKING DRAGLINE at the left, this traveling screening and washing plant, one of two identical units, produces graded gravel for the toe fills at the dam. Raw material is received at the hopper *A*, which discharges into a scalping screen rejecting all boulders over 6 in. The remaining material travels belt *B* to screening plant *C*, from which sand and pebbles under ½ in. are rejected into the excavated pit by boom belt *D*, and desired sized material is loaded directly into railroad cars by boom conveyor *E*.

Aggregate and Toe Material Plants

Huge stationary plant prepares concrete aggregates, and two traveling screening units working alongside dragline cuts produce sized gravel for toe fills from extensive glacial deposits 80 miles from the dam

THE FORT PECK structures require about 5,000,000 cu.yd. of material for concrete aggregate and for the gravel toes and upstream face blanket of the dam. This is being secured from almost limitless glacial deposits at Cole, Mont., whence it is shipped by rail 80 miles to the dam. Here separate and distinct production units have been established to prepare the two classes of material. Sand and gravel for concrete aggregate are screened and washed in an elaborate stationary plant, which has a daily capacity of 100 carloads. About 1,000,000 cu.yd. of aggregate will be required for concrete in the tunnel lining, portal headwalls and spillway structures.

Screened and washed gravel, between ¼-in. and 6-in. sizes, for the dam toe fills and blanket are being produced by two rail-mounted traveling screening plants, supplied from separate pits in the same deposit that furnished the concrete aggregate. The two traveling plants are identical, and are fed by 8-yd. walking draglines working long parallel cuts. They have a daily capacity of 300 carloads.

The glacial deposit lies in the valley of Whitewater Creek near its junction with the Milk. It is 60 ft. thick under an overburden of 2 to 5 ft. of topsoil. Groundwater level is 30 to 40 ft. below the surface, which permitted dry operation in cold weather last winter. A branch of the Great Northern Railroad passes through the pit area, providing railroad haul to the dam site in standard bottom-dump gondola cars. Strings of 70 cars run as through trains from Cole to Wiota, where they are turned over to the government railroad.

Besides the gravel needed for its own day-labor operations in building the dam, the government supplies all concrete aggregates required by the various contractors at the site, and in the early stages of work furnished gravel for road and street construction and for railroad ballast. Bids have been taken at intervals for these materials, f.o.b. Wiota, but so far two contractors operating jointly at Cole have been awarded all contracts. The two contractors, J. L. Shiely Co., St. Paul, Minn., and the Becker County Sand & Gravel Co., Crosby, Minn., operate the Cole pits, leasing the land from private owners.

The town of Cole has grown from a depot and siding to a construction camp of 1,000 population. A 50-kv. transmission line was built into the town to supply power for the various plant units, all of which, except the draglines, are electrically operated. Several pumping plants were installed on both the Milk River and Whitewater Creek, and thousands of feet of pipe were laid to supply great quantities of water needed for washing.

Concrete aggregate is furnished in three sizes: sand, specified from ¼-in. down, with a requirement that from 10 to 30 per cent must pass a 50-mesh sieve, all crusher dust and fine slivers to be removed and all the sand to be thoroughly washed; small gravel varying from ¼ to ¾ in.; and coarse gravel from ¾ to 1½ in.

The aggregate pit was opened up last year to supply small lots to various contractors on street, road and railroad work. Not until the award of the contract for the concrete aggregate for the tunnels was there justification for bringing in electric power and setting up a modern washing and screening plant. All last year the contractor was continually making plant additions to meet the demands, and today he has one of the largest screening and washing plants in the West—one hundred 40-yd. cars in eighteen hours.

In a single deep pit the material is loaded by a 2-yd. electric shovel into 6-yd. side-dump cars, which are hauled by 10-ton trolley electric locomotives to a field hopper large enough to permit dumping nine carloads at one time. Oversize boulders (above 4 in.) make up 20 per cent of the gravel produced, and those over 12 in. are eliminated in the pit by a grizzly before reaching the main belt conveyor leading to the crushing and screening plant.

Material is passed first through a primary crushing and screening plant and is then conveyed to the main plant for final preparation and washing.

Arriving at the main washing and screening plant, the entire product is put through a specially designed scrubber. Deleterious matter, such as clay, goes into the solution and is carried away with the water. Separation of the sand is by two washing cones. For normal operation the plant requires a maximum of 3,500 gal. of fresh water per minute. Control of the water supply is necessary, however, to prevent the washing out of fines with an excess of water when the belt conveyors are not running full.

Railroad cars are loaded with the aggregates on both sides of the washing plant from storage bins. In making up the trains, cars of various classes of materials are placed together, to facilitate unloading at the dam.

Gravel for toe fills

The specifications require that gravel for the toes of the dam be not less than ¼ in. nor more than 6 in. in size. Approximately 4,000,000 cu.yd. will ultimately be required for the toes and for a blanket layer on the upstream face. Under the

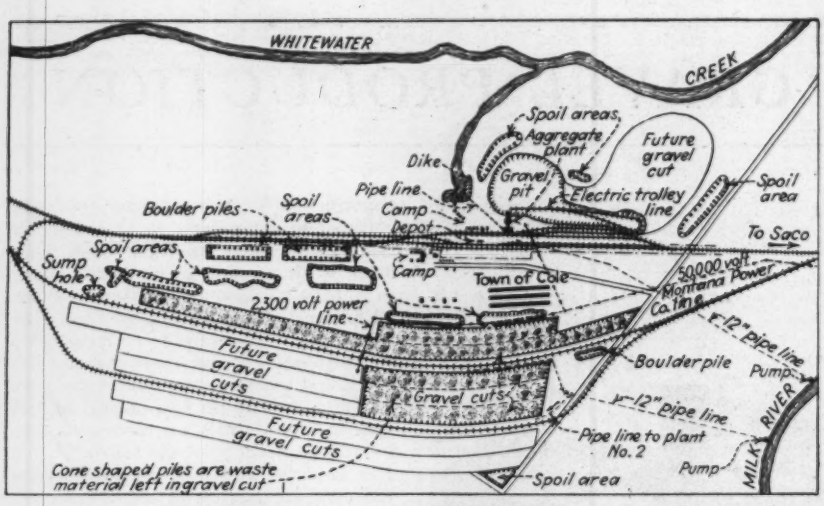


FIG. 23—HIGH-SPEED PRODUCTION of millions of yards of sand and gravel for Fort Peck is possible through this well-designed plant layout at Cole, Mont. Raw aggregate material is carried to a huge stationary plant, but for the sized gravel for the dam toes two traveling screening plants take to the pits.

present contract, 2,600,000 cu.yd. will be loaded. The contract calls for delivery as follows:

	Yd. Per Day
First 30 days	5,000
Next 60 days	6,500
Next 90 days	4,000
Next 30 days	6,900
Thereafter until completion	7,600

The level widespread gravel deposits are ideal for straight-line operation. The production plant consists of two complete and independent units, each composed of a traveling screening plant fed by an 8-yd. diesel walking dragline. An extra steam dragline is used for stripping and as a stand-by machine.

Each traveling unit, operating on a 16-ft.-gage track, is in two sections: one containing the receiving hopper and the scalping screen, which rejects all boulders over 6 in., and one the screening unit, which takes out all material under ½ in. The two units are set in tandem, a belt conveyor leading from the scalping unit to the screen.

The pits were laid out in seven long adjacent cuts, 240 ft. wide and up to 6,000 ft. long, as shown in Fig. 23. The track for the screening plant is laid parallel to the cuts, and between the cut and the railroad track, which accommodates standard cars for loading. The screening plants are self-propelling, and each has a designed capacity of 400 yd. per hour of dry pit-run material. They follow the dragline as it backs away from the excavated cut.

The dragline delivers the material directly from the pit into the hopper, at the bottom of which is a reciprocating feeder dumping the material into a large cylindrical open-end boulder-scalping screen. Large boulders rejected at the end of this screen pass to a boom belt conveyor, which loads them onto trucks. The material falling through the scalping screen is fed to an inclined belt conveyor leading to the main screening plant. After passing through several vibrating screens, the sized product is discharged on to a boom belt conveyor extending out from one side of the plant for loading the cars. Rejected sand is delivered to another boom belt on the opposite side of the plant, which discharges the waste material back into the excavated pit.

Washing, which is possible only in summer, is done at the end of the loading conveyor directly over the cars. This conveyor ends in two side chutes or "pants legs." About 1,000 gal. of water per minute is sprayed over the material as it passes a screen at the end of the conveyor. Dirt and water pass down through the screen and are carried through a waste pipe into the reject pit. The gravel falling into the cars is almost clean enough for concrete aggregate.

Chutes heated in winter

On certain chutes of the screening plant where there was a tendency for frozen material to accumulate during the winter, copper strips carrying low-voltage electric current were installed. Heat radiated from these strips prevented the frosty accumulation of moisture particles by accretion. A 110-volt current was used, the strips not being heated to incandescence, but only to a temperature about that of a household electric iron.

The watertable lies from 30 to 40 ft. below surface. During winter months the pits were excavated only to water, but in warmer weather they are dug to the full depth of gravel, 60 ft. About 50 per cent of the material handled meets specifications, although the natural deposit runs slightly more to coarse material below the water surface. However, due to inability to fill the buckets of the excavators with the wet material from below the watertable and also due to the greater height of hoisting, this increase in the percentage of coarse material is not reflected in over-all increase in plant production during the summer months when deep digging is done.

When handling dry material, the dragline buckets come up heaping full. At first long narrow dragline buckets were used, which resulted in a heavy impact when the loads were dumped into the hopper. Short wide 8-yd. buckets were later obtained, which reduced the impact.

In April, when the operators started to dig below the watertable, the wet material began to cause trouble. The 8-yd. bucket did not reach the hopper with over 6 yd. of wet material. It was found that when the wet material was handled exclusively, the belt conveyor between the scalping and the screening plant would not satisfactorily carry the wet gravel up the incline. This trouble was partly overcome by speeding up the belt to 530 ft. per minute. As an experiment, ¾-in. holes were drilled in the buckets, to permit the escape of water during the period of hoisting. Then alternating loading of wet and dry material was tried. This worked better, and at present three wet loads are picked up followed by one dry load. The dry load tends to clean out the screening plant and belt conveyors.

Some delay is caused by the presence of large boulders in the deposit. Whenever the crane operator can see one in the bucket, he dumps the load on the stripping dump; otherwise they appear on top of the hopper and must be lowered to the ground by hand or with a crane.

About two miles of track are required to serve the seven longitudinal pits. Trains of empty cars are taken to the north end of the yard and are split up between the two tracks leading down to the screening plant (Fig. 23); the cars are switched by tractors.

Since the beginning of operation on the project 45,924 cars of gravel had been loaded out by these traveling plants up to July 18 of this year.

One of the interesting railroad features is the scale installation of the Great Northern Ry. located one mile east of Glasgow. These scales are of the latest type and are said to be the only track scales in the United States that can weigh cars of different lengths while they are in motion. A small trip lever is located next to the ball of the rail at the rear end of the scale platform; the flanges of the car wheels depress this trip as they pass, and when the flange of the fourth car wheel depresses the lever the weight is automatically recorded to the nearest 200-weight. Trains move at a speed of 1¾ m.p.h. during the weighing.

Direction

Captain C. H. Chorpening is in charge of gravel production for the government, with R. L. Campbell as engineering representative at the pits. For the joint firms of J. L. Shiely and Becker County Sand & Gravel Co., S. T. Harrison is superintendent.

Automatic Pumping Control Features Central States Waterworks Meeting

Two-day convention at Pittsburgh offered a diversified program of topics dealing with rate schedules, public relations, chlorine disinfection, spillway designs and treatment of Monongahela water

A PAPER dealing with automatic and remote-controlled electrically operated pumping stations was a highlight of the 37th annual meeting of the Central States Section of the American Water Works Association, held at Pittsburgh, Pa., on August 22-23. Frank A. Barbour, president of the national organization, addressed the convention and urged greater emphasis in building up membership. He stated that only 7½ per cent of the waterworks systems in the United States (875 in a total of 12,000) are affiliated with the national association. Before adjournment, the 170 delegates attending the meeting elected the following officers for the coming year: W. W. Morehouse, Akron, Ohio, chairman; R. Hulbert, of Detroit, Mich., vice-chairman; and H. Lloyd Nelson, of Pittsburgh, Pa., secretary-treasurer. T. L. Young, of Chester, Pa., was elected a trustee to fill the vacancy occasioned by the death of G. M. Keefer.

Pumping automatically controlled

Modern methods of controlling electrically operated pumping stations by automatic devices and through remote central station control were discussed in a paper by S. A. Canariis, electrical engineer of the Pittsburgh water department. Widespread use and development of electrical control mechanisms by the power utilities have opened possibilities for the adaptation of similar equipment to waterworks operation.

The complications of modern water distribution, particularly where there are several pumping stations, are easily coordinated with automatic devices when all the stations are operated by a remote-control system from a central operating office. One of these supervisory systems, known as the audible type, employs dispatcher equipment similar to the conventional dial telephone; pumps and accessories are controlled by sending out coded signals that actuate relays. Visible types of supervisory control are similar in function, except that switches and miniature indicating lamps are used to actuate the relays and signal proper operation.

Simplified water rates urged

In a paper by Nathan B. Jacobs, president of Morris Knowles, Inc., of Pittsburgh, waterworks officials were warned not to follow the example of the power utilities in setting up complicated and involved rate schedules, or else there would be destroyed in the minds of the consumers the feeling of trustworthiness that now exists. The present scheme of a one-meter schedule, consisting of a minimum charge combined with a step-block charge, was held to be sufficiently flexible and universally applicable to all customers from the smallest home to the largest industry. The author expressed the belief that the waterworks industry would have nothing to gain by accepting either the careful specifications or the multiplicity of factors used in determining electric rates.

Typhoid checked by water treatment

Reviewing the changes in water-supply practice as related to public health from the viewpoint of 25 years' experience in contact with 700 plants, Howard E. Moses, assistant chief engineer of the Pennsylvania department of health, emphasized the important rôle played by water treatment in controlling disease. In 1905 the death rate in Pennsylvania from typhoid alone was 54.8 per 100,000, but due largely to safe water this has been successively lowered, and in 1934 the mortality rate was only 1.3 per 100,000—a reduction of 97 per cent.

Despite the progress of waterworks operation in the last quarter century, many problems still remain to be solved, among which were recommended: safeguards for watershed protection, new processes to treat water of complex composition, methods of eradicating industrial-waste pollution, research on foreign substances in water supplies that may be toxic and detrimental to public health, and standardization of plant record-keeping, so that there will become available comparable results instead of masses of information, valuable but not readily analyzed.

Difficulties in treating water

The difficulties in treating water taken from the Monongahela River, which receives the wastes from scores of industrial plants, were described by Frank W. Bouson, chief chemist of the South Pittsburgh Water Co. Quantities of chemicals are allowed to enter the main stream and its tributaries without regard for other indispensable purposes for which the river water must be used. Drainage from abandoned mines has complicated matters by destroying the natural alkalinity of the water, so that the flow is predominantly acid throughout the year.

Efficient filtration is obtained without the use of alum, because the acid salts in the river are sufficient to coagulate completely the settled water; the equivalent of the acid salts of aluminum in the raw water, in terms of alum, have been as high as 10 grains per gallon.

Model studies of spillways

Gale Dixon, of Youngstown, Ohio, described and illustrated in motion pictures some model experiments on prevention of erosion below overfall dams. Pointing out that the sheet flow phenomenon of spillway aprons may do enormous damage by tearing out the toe of a dam, he went on to explain how the hydraulic-jump principle has been utilized to dissipate this destructive energy. Three types of construction were investigated: a bucket or trench at the base of the spillway, a double row of diamond-shaped piers, and a 4:1 straight spillway slope with a weir at the base. The latter design, developed by the Miami Conservancy District in 1915, was considered the most desirable, and is now being used on the TVA dams.

Chlorine disinfection

Chlorine gas was held to be many times more germicidal and faster in action than chloramine, by Prof. W. L. Mallman of Michigan State College, who described his research work in chlorine disinfection. An increase in effectiveness of chloramine was noted when it was applied to solutions above pH 8.0, the explanation being that chloramine gave up its chlorine content more readily in an alkaline reaction. Sodium or calcium hypochlorite, used for chlorination, was found to be greatly increased in effectiveness by acidulating the salts with hydrochloric acid. This reaction lowers alkalinity and releases nascent chlorine gas.

A practical demonstration of what the Indianapolis Water Co. is doing to emphasize public relations in the waterworks field was offered by Miller Hamilton. His presentation of a motion picture and synchronized lecture entitled "Behind the Water Front," illustrating in a simple but convincing manner the method of operation and importance of a modern city waterworks, has been given more than 200 times before schools, civic and church groups in Indianapolis.

An open forum, conducted near the close of the meeting by Prof. L. V. Carpenter, of the University of West Virginia, encouraged exchange of ideas bearing upon operation and maintenance problems. The convention was concluded with inspection trips to the 60-acre Aspinwall filtration plant and to the electrically controlled pumping stations of the Pittsburgh water system.

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Planned Local Roads

THE REGULATIONS just issued for selecting secondary roads for improvement under the relief-works act contain provisions that promise a degree of road-system development not reached in the past under decentralized administration. Generally the improvement of farm-to-market roads has disregarded continuity of route and proper standards of construction—standards that assure reasonable permanence of the result. Under the relief-works regulations, (a) the accepted improvement must connect with an improved road, (b) it will be given preference on the basis of present and potential traffic densities, (c) the structure must conform to sound stage-improvement standards, and (d) maintenance must be guaranteed. In brief, these regulations demand that secondary-road improvement with federal money shall contribute to the development of a real highway transportation system, in both construction and operation. If this purpose is adhered to, relief is assured from much of the enormous waste of money on secondary and tertiary roads in the past.

Still Far to Go

STATISTICAL SUMMARIES of the present state of residential building activity may lead to the erroneous impression that we are experiencing something of a boom. Thus a news release from the Federal Home Loan Bank Board based on Department of Labor figures for cities of more than 10,000 population states that, "For the first seven months of this year new residential construction amounted to 42,026 family dwelling units, which was 146 per cent greater than the number of home units provided in the corresponding period in 1934." There can be no quarrel with the accuracy of the statement, but it is pertinent to ask how 1934 compared with predepression years. And the answer is bad, very bad indeed. In 1934, 30,000 dwelling units were built. In that same year, and in every other year, as many dwelling units were destroyed by fire alone. A 150 per cent increase over 1934, to 75,000 units, is less than 15 per cent of the annual volume of residential building in every year from 1925 to 1929. Actually the housing deficiency which began in 1929 is still increasing by leaps and bounds. If the present rate of housebuilding were multiplied fifteen times, we would still need four years to make up the accumulated deficiency of more than two million dwelling units existing at the present time. The present upturn in activity, gratifying though it be, should be appreciated for what it is—namely, just a reversal of trend.

Adequate Planning Needed

ONE STATEMENT in the most recent report of the governor's Commission on Unemployment Relief (New York) has a significance extending far beyond the limits of the Empire State. The commission, in reporting upon the efficiency of work-relief projects, said: "Adequate design, planning and specifications are of such vital importance that they should not be slighted. The shortcoming prevailing in this regard is more significant than the numerical figures cited would suggest because of the peculiarly deleterious effect of planning inadequacy upon attainable results." This fact has impressed itself upon most of those who have had any close contact with relief operations. Seemingly it has been patent to nearly everyone except to those in Washington who held the purse strings. Possibly because advance planning was something intangible that could not be specified in detail, Washington authorities have been unwilling to provide for it. In the case of PWA operations, lack of money for advance planning kept many projects from being put forward. Right now as the fall and winter season approaches, a time when unemployment needs may be expected to increase, a large amount of planning for relief projects should be in progress. The resultant gain in efficiency and value of the work would offset the initial cost many times.

Two Kinds of Business?

WHETHER as citizens or as construction men, we may take satisfaction in the failure of Congress to adopt the plan for setting up a special class of business and industry to deal with the government, as proposed by the Walsh Bill. The bill would have divided American industry into two groups—one for the service of the government, the other for private service; the former operating under regulations set up and from time to time changed by the whim of Washington officials, the latter operating under the normal dictates of economics and law. How such an arrangement would work, and whether it would prove stable, is difficult to forecast, but the chances are all against its success; and of course failure would react most seriously on business as a whole. It was a crackbrained scheme, and every citizen may congratulate himself on the negative attitude of Congress toward the plan. Construction men have even greater reason to feel thankful than other citizens, for their existence would have been affected in a peculiarly unfavorable manner. Labor relations in the construction field would have been disorganized, and government contracting would have been set up as a distinct class, a division that would weaken whatever stability construction now has. The troubles of the industry would have been greatly intensified. This danger is over for the present, and by next January the members of Congress will have had time to ponder on the meaning of legislation of this kind.

Federal Flood-Protection

FOR OTHER REASONS the failure to pass the flood-protection bill is a matter for gratification. Unquestionably the country needs extensive flood-protection work, but whether this should be carried out as a national responsibility or should remain local is an issue too broad and important for hasty disposition via the pork-barrel route. Up to now this type of improvement has been strictly a local responsibility. No reason has yet appeared for relieving the states of their duty in the premises. Has federalization proceeded so far as to warrant the government's taking over flood protection and putting it into the federal class along with navigation improvement? Such a step would in any event have far-reaching influence on the future development of engineering. It would also imply the assumption of federal responsibility for flood damage anywhere and everywhere. The costs en-

tailed by such a system, as well as the prospects of log-rolling on a huge scale, are serious to contemplate. The situation created would be even worse than that in the field of navigation improvement, for with respect to the latter we are moving rapidly toward a policy of placing the cost on traffic, which will provide some safeguard against unsound schemes. Flood protection, on the other hand, holds out no prospect of similar liquidation or assessment of benefit charges. It would open the door wide to political exploitation and bureaucratic dictation.

Fingertip Control of Water Service

THE PRACTICAL POSSIBILITIES of modern control devices in electrically operated water-pumping stations are instructively illustrated by recent installations at Pittsburgh. Topographical conditions in this city make water distribution a major problem and necessitate a complex system of reservoirs and pumping stations to maintain adequate supply and pressure facilities. It is of interest, therefore, to note the adaptation of automatic and remote-control equipment, borrowed from the experience of electric distribution, to aid in efficient and reliable pumping-plant operation. New pumping plants have been built to function without attendants and are operated either by automatic or remote-controlled devices. It is expected that eventually a combination of these two types of equipment will be completed, so that all the pumping operations of the city will be coordinated and directed by one central dispatcher. Since standard electrical control equipment is now universally available and a telephone circuit can be rented for a small fee, similar control is readily applicable to any water system that needs it. To indicate its advantages, we have the fact that the entire control installation for Pittsburgh's 4-m.g.d. Saline continuous pumping plant cost less than one year's expense for maintaining operators. Waterworks engineers will need no invitation to investigate these new developments, which offer possibilities of substantial reduction in operating cost and increased reliability.

Making History at Fort Peck

THROUGH whole-hearted cooperation on the part of the engineers and contractors, *Engineering News-Record* is privileged to place before the engineering profession in this issue a comprehensive account of the operations of damming the Missouri at Fort Peck. The work constitutes a model example of what present-day technical skill can accomplish with the aid of modern tools. It enlists general interest because of its impressive dimensions and because it was undertaken primarily to relieve unemployment. To engineers, however, it is important by reason of the inherent difficulty of its problems and the admirable manner in which they are being attacked.

For adequate comprehension of the operations it is necessary to have clearly in mind what the Fort Peck project is. A dam 250 ft. high is being thrown across the Missouri River at a point where its valley is a mile and a half wide; it will be many times larger than any earth dam before attempted. Its accessories are as gigantic as the dam itself.

Nature has constructed dams on incomparably greater scale, of course. The enormous embankments it has placed across valleys, holding back much deeper lakes, make one feel that human work even so large as that at Fort Peck is puny and simple. But nature could take many chances that man may not take. Many of its dams failed and deluged the valleys below; that must not happen at Fort Peck.

The problems presented by the undertaking are exceptionally difficult. Complete assurance of safety must be present at all times. The only suitable material at hand being the sand and silt of the river plain, the dam necessarily is an earthen barrier built by hydraulic placement. The difficulties of constructing a tight and safe dam on the soft valley bottom, of bypassing the river during construction, of assuring enduringly sealed abutments, and of providing securely for discharge and flood spill, would be weighty even were the structure of ordinary size. They are made truly formidable by its gigantic proportions.

Large hydraulic-fill dams always present special hazards, especially when they must be built in separate sections, and soft foundation ground does not simplify the problem. The extremely wide dam designed to meet these conditions, the deep sheetpile cutoff wall, the diversion and outlet tunnels through the hillside shale, and the remarkable spillway, invite close study. The Fort Peck Dam will make a notable addition to engineering history.

Fort Peck is no less distinguished in its construction accomplishments. A task so difficult and large deserved an ample preparatory period for studies and planning in order to do it full justice, but circumstances precluded this. The job had been chosen as one of the major items of the 1933 construction-for-employment program, and accordingly work had to begin without normal preparation. Plans were only in rough preliminary form, yet the engineers had to make a start at once, in late autumn, and keep large forces of men at work throughout a rigorous winter, building dredging boats, arranging transportation and living facilities, exploring bottom soil and abutment rock, preparing and letting contracts, providing water and power supply, in order that construction might go ahead in earnest in the spring. In a theater of operations spread over dozens of square miles, far from a base of supplies, they had to develop and work out the multitude of engineering and construction problems of the job even while work was already in progress.

The record speaks eloquently of how they discharged their responsibility. No engineer can fail to take intense interest in what they did and how it was accomplished. The fact that from 5,000 to 7,000 men have been continuously at work on the Fort Peck job tells more conclusively than any other figure of the attainment of the basic re-employment objective. The high level of efficiency reached at the same time is attested by the volume of physical accomplishment to date. To mention only a few typical items: dredging was begun before the end of the first season, the diversion tunnels were pierced through in five months, and at present some fifteen million cubic yards of dam embankment are already in final place.

Construction performance in fact dominates the Fort Peck picture, and completion of the project will add as significantly to the annals of construction as to those of engineering. Greater works will be made possible in future by virtue of what is being done today in the valley of the upper Missouri.

CURRENT NEWS

Deadline Announced For Applications For Relief Funds

Washington Correspondence

ALL APPLICATIONS for a share of the $4,800,000,000 appropriated by Congress for emergency relief must be in the hands of the Division of Applications and Information of the National Emergency Council by Sept. 12, according to a letter addressed by the President to the heads of the various departments and agencies. Other deadlines are set as follows: Approval by the Division of Applications, Sept. 17; action by the Secretary of the Treasury and the Comptroller-General, Sept. 24; requests for bids on contract operations, or start of force account work, Oct. 22; award of contracts, Dec. 15.

Such is the ambitious program scheduled in the latest drive to put men to work. Published without preliminary warning, it is bound to bring forth a flood of applications hitherto delayed for more or less justifiable reasons. Whether or not the schedule will be adhered to remains to be seen; if it is, there will undoubtedly be serious curtailment in many fields. For example the Rural Electrification Administration with $100,000,000 to spend has yet to submit a single specific application for approval.

It is self-evident that a complete program for such a large amount distributed over thousands of small projects cannot possibly be submitted in the few days remaining before Sept. 12. With this consideration in mind, it seems probable that after the deadline has been passed justification will be found for a great many applications, although the ruling will undoubtedly provide an excuse for rejecting distasteful projects.

PWA Time Limit set at Sept. 16

Public Works Administrator Harold L. Ickes has instructed all officials of the PWA organization that applications for PWA projects could not be received after Sept. 16.

With applications from communities willing and able to bear 55 per cent of the cost of PWA construction projects to win a 45 per cent grant approaching the $1,000,000,000 mark, applications already filed threatened to exceed funds available.

Communities, intending to participate in the PWA program with a 55 per cent local contribution, which have not yet sent their applications to the PWA director of their state, have opportunity to do so within the next 25 days. During the past week, the influx of applications from local public bodies to PWA has been so heavy that the Works Progress Administration has not been able to check the applications and the unemployment reports in the areas involved as rapidly as they have been received.

Although a number of projects, on which legal or engineering difficulties prevent prompt preparation of formal applications, will probably be lost, the general effect of the President's deadline of Sept. 12, on PWA is not considered serious by Secretary Ickes. Of the new PWA fund $248,000,000 has been allocated for housing and $70,000,000 for other purposes. Applications now on hand total about $1,000,000,000 and more are coming in at rate of several hundred per day.

St. Louis's $30,000,000 sewer project on which bond election is scheduled for Sept. 10, the Santee-Cooper hydro-electric project in South Carolina on which a legality test is pending and a $46,000,000 gas pipe line from Texas to Detroit are among the large projects in danger.

Ickes expects a special dispensation for housing although the program is being speeded up as much as possible. Land acquisition is the largest delaying factor in the housing progrm. Ickes admits that the Sept. 12 deadline is not as troublesome as later ones will be, as municipal and state laws, requiring a definite interval between contract advertisements and awards, may be pinched between a delayed approval and the Oct. 22 or Dec. 15 limits.

Congress Gives Approval for Tri-State Sewage Board

Under the terms of a joint resolution passed by both the House and the Senate the states of New Jersey, New York and Connecticut have been authorized to form a commission consisting of representatives of the three states to determine methods for the abatement of pollution in the waters adjoining New York Bay. Congressional authorization was anticipated, however, and the board held a preliminary meeting on August 15, as reported in last week's issue of this journal.

Under the congressional authority all sewage discharged into class A waters of the district shall first have been so treated as to remove all floating solids and at least 60 per cent of the suspended solids, and to effect a reduction of organisms of the B coli group (intestinal bacilli) so that the probable number of such organisms shall not exceed one per cubic centimeter in more than 50 per cent of the samples of sewage effluent. In waters used primarily for bathing, this bacterial standard need not be required except during the bathing season. Also in class A waters, which are to be used primarily for recreational purposes and the development of fish life, there must be reduction in the oxygen demand of the sewage effluent of not less than 50 per cent. All sewage discharged into class B waters which are not to be used primarily for recreational purposes or for the development of fish life shall have no floating solids and not more than 90 per cent of suspended solids. The oxygen demand must not be more than 30 per cent. All streams flowing into the district shall be under the jurisdiction of the commission so that more efficient control may be exercised over the amount of pollution entering the district.

Advisory Committee Moves to Halt WPA Loans For PWA Work

UNDER the terms of a recent resolution adopted by the Advisory Committee on Allotments applications for PWA projects on a loan and grant basis cannot be switched as applications for WPA funds except with the consent of PWA Administrator Ickes.

According to the resolution no community able to finance a project on a loan and grant basis will be allotted money on more favorable terms from funds at the disposal of the committee even though that community neglects or refuses to produce its share of funds to make its project eligible as a PWA project.

Carrying out this broad policy, the Advisory Committee on Allotments declared the consent of the Administrator of Public Works would be required before any applicant who filed application for a public works project might withdraw such application to seek funds through other agencies.

This action was taken after PWA had received nearly 4,000 applications for projects totaling almost $1,000,000,000, which established the fact that sufficient communities were both able and willing to contribute 55 per cent of the cost of their projects in order to get 45 per cent federal grant.

The policy was laid down to block any efforts of communities, which are able to bear their share of the cost, and which might seek to secure special favor by unwarranted declarations of poverty in order to dodge financial responsibility. As the allotment of WPA funds means that the federal government bears a larger share of the cost this scheme has definite attractions.

PWA Inspection Group Reports On Applications in South

Administrator Harold L. Ickes announced on August 26, that reports from the PWA field inspection group now in the South, indicate that applications for loans and grants totaling more than $1,000,000,000 for needed local projects will be filed with PWA before Sept. 16, the deadline for making applications.

State directors said that they will have more than $155,000,000 of applications in Washington and ready for submission to the Advisory Committee on Allotments. This volume of applications from the South and the border states is expected to be increased materially when reports are received from Mississippi, Alabama, Florida, Georgia, North and South Carolina and Virginia.

William H. Gravell, PWA state director for Pennsylvania, said that he would have at least $62,000,000 worth of public works projects for which local communities are willing to share 55 per cent of

the total cost. About three-fourths of the Pennsylvania applications are expected to be for school houses. Although the city of Philadelphia made no applications under the original PWA program, a number of school projects recently have been received from the city's board of education. Up until last Aug. 22 the state director's office had received 140 applications for PWA projects costing about $30,000,000, with a fair prospect of increasing this total to 250 projects at a total cost of $62,000,000.

In West Virginia, the PWA state director, M. L. O'Neale, reported that he had received about 40 applications for projects valued at $5,500,000 and that before Sept. 16 he would have in Washington about 65 applications for loans and grants totaling more than $10,000,000. The West Virginia director said that a number of communities in the state were holding back in the belief that they might receive more liberal terms from the federal government.

The PWA state director of Kentucky, George H. Sager, Jr., reported that 79 applications for local projects already had been received, with the expectation that before Sept. 16 there would be nearly three times as many with a value of more than $30,000,000.

Tennessee cities and towns are expected, within the next fortnight, to increase the number of applications to 130 projects with a value of $60,000,000.

In Little Rock, Ark., PWA state director, Alexander Allaire, reported receipt of applications for 55 projects valued at between $3,000,000 and $4,000,000. Mr. Allaire said that by the closing date for applications he would be able to send to Washington at least 100 projects calling for $15,000,000, which will be almost a third more than the local applications received from Arkansas under the original PWA program.

The PWA inspection group, composed of Elmer W. Clark, Assistant to the Administrator; Edward H. Foley, Jr., Director of the Legal Division; Philip M. Benton, Director of the Finance Division; Arthur J. Bulger, Assistant Director of the Engineering Division; Aubrey E. Taylor, Assistant Director of Public Relations; Dan H. Wheeler, Administrative Attorney and Joseph K. Vinson, Secretary, returned to Washington on Aug. 27 after a 10,000 mile airplane tour made to expedite the relief work program.

Massachusetts Will Build 500 Miles of Highway Sidewalks

In order to reduce pedestrian accidents on state highways, Massachusetts will begin a program of sidewalk construction totaling 500 miles along state roads. The work is estimated to cost about $4,000,000. At present the state has 1,852 miles of state roads and only about 30 miles of sidewalks along them. The plans call for the use of bituminous material bordered with concrete or granite curbing. No sidewalks will be provided along the Newburyport Turnpike because plans have already been prepared for extensive rebuilding and widening. In general, sidewalks will be provided in the more populous sections with footpaths interconnecting these. Work will begin at once, in view of the recent $13,000,000 bond issue authorized by the state for public works projects.

Principles for Secondary Road Projects Outlined by Bureau of Public Roads

PRINCIPLES for the selection and construction of secondary or feeder roads in rural areas to be improved with funds appropriated by the Emergency Relief Appropriation Act of 1935 were outlined on Aug. 21, by the Bureau of Public Roads of the Department of Agriculture. The rules were sent to state highway departments for their use in planning secondary road projects in the states. Availability of employable skilled relief workers, possibilities of creating economic and social values in the areas served, and present and potential traffic are among the factors recommended for initial consideration in the rural roads program.

Not less than $50,000,000 of the $200,000,000 allotted for highways from the relief works funds is to be applied to secondary roads. The highway funds were apportioned among the states on June 4, 1935. Secondary or feeder roads are defined as rural roads not included in the federal-aid or state highway system in the states which have not taken responsibility for county or township roads. In states which have taken such responsibility former county and township roads are considered secondary roads. State highway officials are authorized to prepare programs of secondary road construction, which are first examined by the district engineer of the Bureau of Public Roads. After he approves them they are submitted by the state highway department to the state director of the National Emergency Council and the state administrator of the Works Progress Administration. Upon receiving the approval of these two officials, the programs are then returned to the district engineer of the Bureau of Public Roads, who forwards them to Washington for final action. The principles are intended to promote an economical and judicious use of the funds provided for the building of secondary roads. In many areas the feeder roads will serve as direct links to state and federal highways.

Availability of employable relief workers of sufficient skill is to be the primary consideration for allotment of funds for the construction of secondary or feeder roads in any area. But of almost equal importance in the selection of projects are the possibilities of creating economic and social values in the areas served by the proposed improvements.

Abandonment recommended in unproductive areas

As a factor in the determining of the value of the projects emphasis is placed on the fact that it is as important to consider the values that may result by denying improvements and thus encourage abandonment of unproductive areas as it is to consider the positive values resulting from improvements in desirable areas. In application of this principle the location of submarginal agricultural land and the location of federal resettlement projects and other predictable developments likely to increase density of land settlement is to be carefully considered and in the absence of strong local reasons projects proposed for construction of secondary or feeder roads in submarginal areas should be denied. Subject to these considerations preference will be given to roads that connect farms with railroad and water loading points, schools, churches and community developments.

In the absence of compelling reasons to the contrary, sections of secondary or feeder roads proposed for improvement should connect with previously improved highway systems, and preference will be given to projects that connect with the improved system at two ends.

No proposed improvement will be approved unless a definite need for such improvement can be demonstrated, and the need will be indicated by the existence of either hazard to travel at any season of the year or excessive maintenance cost of the road in its present state.

Density and character of traffic to be considered

In selecting roads found to be in need of improvement the relative importance and amount of their potential traffic shall be taken into consideration. The character of the traffic is to be considered as well as its density, since the aim of the program is to improve roads that to the greatest extent facilitate transportation of farm products and extend to rural areas the benefits of urban development.

In making a selection between roads of similar usefulness in respect to character of traffic their estimated potential traffic is to be the basis of consideration. The potential traffic order shall be assumed to be the same as the order of the present daily (24 hour) traffic density. All proposals for the improvement of secondary or feeder roads are to be accompanied by a certified estimate of present average daily traffic density, based on actual counts. As nearly as possible upon the basis of traffic information available, or quickly obtainable, the object is to provide for the improvement of secondary or feeder roads in any county in the following order: Roads serving traffic in excess of 100 vehicles daily; roads serving traffic of densities between 50 and 100 vehicles daily, and roads serving less than 50 vehicles daily.

Projects must bring substantial improvement

No project is to be approved unless it has been determined that the work proposed will result in a substantial improvement of the roadway. Work properly classified as maintenance will not be approved. Improvements made with relief funds shall be capable of maintenance under the existing and estimated potential traffic at reasonable cost. Authorities legally charged with the administration of secondary or feeder roads selected for improvement shall be required by specific agreement, to maintain roads after improvement.

Improvements of secondary or feeder roads made under the administration of county or other local highway officials must conform to standards established for improvement of roads of like class, traffic density and other conditions, by the respective state highway departments with the approval of the U. S. Bureau of Public Roads. It is not contemplated under this direction that the high standards of construction ordinarily established for trunk and state highways shall be carried over

into work on secondary or feeder roads, but it is anticipated that the work done shall result in material betterment of the existing condition.

The Farm Roads Advisory Committee, which has formulated these principles governing selection of secondary road projects, consisted of the following members: Dr. A. G. Black, chief of the Bureau of Agricultural Economics, chairman; H. S. Fairbank of the Bureau of Public Roads; Roy Hendrickson of the Land Policy Committee; Perry A. Fellows, chief engineer of the Works Progress Administration; Willard E. Herring of the Rural Electrification Administration; Hugo F. Kuehne of the Rural Resettlement Administration; Harlee Branch, second assistant postmaster general.

Sale of Hetch-Hetchy Power Found to Violate Federal Act

Power developed as part of the Hetch-Hetchy water supply system is being sold by San Francisco in direct violation of the terms of the Raker Act, which prescribed the conditions under which the Hetch-Hetchy system could be constructed on government property, according to a ruling of Secretary Ickes made public on Aug. 24.

The ruling was made respecting a controversy which has been under way for about twelve years. It is based upon the contention that San Francisco is selling to the Pacific Gas and Electric Co. for resale surplus power from the Moccasin power plant, despite the prohibitions against selling or letting the right to sell the power to a private company contained in the Raker Act, the act that authorized the city to construct its water project within the Yosemite National Park.

Hetch-Hetchy surplus power is now being distributed by the Pacific Gas and Electric Co. under a contract made with San Francisco on July 1, 1925, in which the company was temporarily "employed" to distribute the power pending the construction or acquisition of a city-owned system. Its compensation is 73 per cent of average revenue derived from the "consigned" power, the balance being paid over to the city. The agreement assumes that 24 per cent of the power delivered to the company at its Newark sub-station would be lost in transmission and would not be paid for. For the purposes of the contract it was assumed that the average revenue received was 2.383c. per kw.-hr., a figure based upon the 1924 rate schedule. The contract could be terminated by either party on one day's notice, and also provided for "immediate cancelation upon request or demand of the Secretary of the Interior of the United States should he hold that in his opinion the agreement violates any provision of the laws of the United States in general, or the Raker Act in particular."

San Francisco officials were surprised by the decision and no plans for complying have been developed. Voters repeatedly have refused to sanction establishment of a municipal distribution system and city officials point out that either the general or revenue bond issue plan suggested by the Secretary probably would be defeated if submitted to voters now. Municipal distribution would duplicate the private system, would necessitate steam standby plants and would deprive taxpayers of present annual revenue of $2,000,000 from the wholesale power contract.

New Orleans Sewerage Work To Be Paid from Local Funds

Continuation of existing contracts for projects on which work had been started but for which funds were held up by refusal of the PWA to sign vouchers will be effected by the New Orleans Sewerage and Water Board. The board, in a resolution, directed the contractors' work to be continued and payment to be made from the board's public improvement fund which now has $800,000 which can be used. The refusal of the PWA to permit vouchers to be drawn on New Orleans banks in which money from a loan and grant are on deposit is based on the terms of an act adopted by the state legislature vesting full control of such expenditures in a state board.

PWA funds amounting to $1,800,000 have been deposited in New Orleans banks for payment of the sewerage contracts but the PWA state engineer has withheld approval of the board's warrants drawn in favor of the contractors and payable out of these funds. The board decided to proceed with its program of PWA projects and to pay contractors for the work done out of the public improvement fund and to continue to pay them until the government releases the $1,800,000.

Immediate payment of sums due contractors who have been working on the projects calls for disbursement of $116,000. The money will come from the public improvement fund in which there is at present $2,000,000, of which $1,200,000 is earmarked for bond service.

SOCIETY CALENDAR

AMERICAN WELDING SOCIETY, fall meeting, Chicago, Ill., September 30 to October 4.

AMERICAN PUBLIC HEALTH ASSOCIATION, annual meeting, Milwaukee, Wis., October 7-10.

NATIONAL SAFETY COUNCIL, annual congress, Louisville, Ky., October 14-18.

PUBLIC WORKS ENGINEERING CONFERENCE, joint meeting of the American Society of Municipal Engineers and International Association of Public Works Officials, Cincinnati, Ohio, October 14-16.

INSTITUTE OF TRAFFIC ENGINEERS, Sixth annual meeting at Louisville, Ky., October 15-16.

AMERICAN SOCIETY OF CIVIL ENGINEERS, fall meeting, Birmingham, Ala., October 16-18.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION, White Sulphur Springs, W. Va., October 16-18.

AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, annual convention, Miami, Fla., December 9-12.

ROCKY MOUNTAIN SECTION, American Water Works Association, annual meeting, Denver, Colo., September 16-18.

NEW ENGLAND WATER WORKS ASSOCIATION, fall convention, Providence, R. I., September 17-20.

NEW ENGLAND AND NEW YORK STATE SEWAGE WORKS ASSOCIATIONS, joint meeting at Schenectady, N. Y., October 4-5.

EXAMINATIONS for registration of engineers and land surveyors will be held in the near future as follows:

IOWA—By Iowa State Board of Engineering Examiners at the State House, Des Moines, Sept. 4-5.

LOUISIANA—By Louisiana State Board of Engineering Examiners at the offices of the Board, New Orleans, Sept. 9-10.

DIESEL LOCOMOTIVE FACTORY OF WELDED FRAME CONSTRUCTION

A factory for the manufacture of diesel-electric locomotives is being built at McCook, Ill., for the Electro-Motive Corp., a subsidiary of General Motors. This is the largest complete unit erected for the manufacture of heavy durable goods in a number of years. All the structural steel is being electrically welded on the job, and more than 2,000 tons of steel are being used.

The main erecting aisle, 550 ft. long with a 100-ft. clear span, and 49 ft. high, has been designed to carry a traveling crane with a capacity of 200 tons and a dead weight of 205 tons. The steel work of the main assembling unit is heavy enough to support a one-story drafting room if one should be considered necessary later on. The roof is of pre-cast cement slabs, supported on steel girders.

Nine buildings are included in this project, including a three-story office building of 40x140 ft., an erecting and machine shop building of 170x550 ft. and annealing ovens, 22x200 ft. The machine shop which adjoins the erecting building is 550 ft. long and 64 ft. wide and is served by two traveling cranes of 20 ton capacity and two auxiliary traveling cranes of 30 ton capacity to supplement the 200-ton crane in the main erecting aisle. The annealing ovens are designed to accommodate the entire frame of the largest locomotive at one heat. The Electro-Motive group when completed will have its own diesel power plant, water supply and sewage disposal system.

Construction work is being done by the Austin Company, and is scheduled to be completed on Sept. 11.

Washington Highlights

By Paul Wooton

Many measures of direct interest to the construction industry were passed at the session of Congress just closed. They deal with work relief; rivers and harbors; soil erosion; TVA; truck transportation; social security; railroad pensions; taxes; holding companies and labor relations. Measures which made progress, but which failed of passage, include revision of Mississippi flood control plan; ship construction subsidy; regulation of inland waterway and coastwise carriers; 30-hour week; continuance of code provisions in connection with government contracts. The rivers and harbors bill has not yet been signed by the President.

Appropriations during the session of Congress just closed total nearly $10,000,000,000.

The Flood Control Bill that would have authorized the expenditure of $500,000,000 on flood control projects scattered throughout the country and the Walsh Bill empowering the government to impose maximum-hour and minimum-wage standards on all those contracting with it were among the bills that failed to pass before Congress adjourned.

Failure of the third deficiency bill is not expected to interfere importantly with the carrying forward of the work for which the $92,000,000 in that measure was intended. Means of financing expenditures already authorized will be worked out, it is believed. Among the items in the deficiency bills were: social security funds $76,000,000; motor carrier control $1,250,000; labor board $245,000,000; soil conservation $13,000,000; central statistical board $101,000.

There has been absolutely no curtailment in the authority of PWA Administrator Ickes, despite published statements to the contrary.

"Sole power to recommend loans and grants remains in the Public Works Administrator," says a formal White House statement. In the interest of consolidating information recommendations for public works will go to the President through the allotment board. This is the only change made, the White House says.

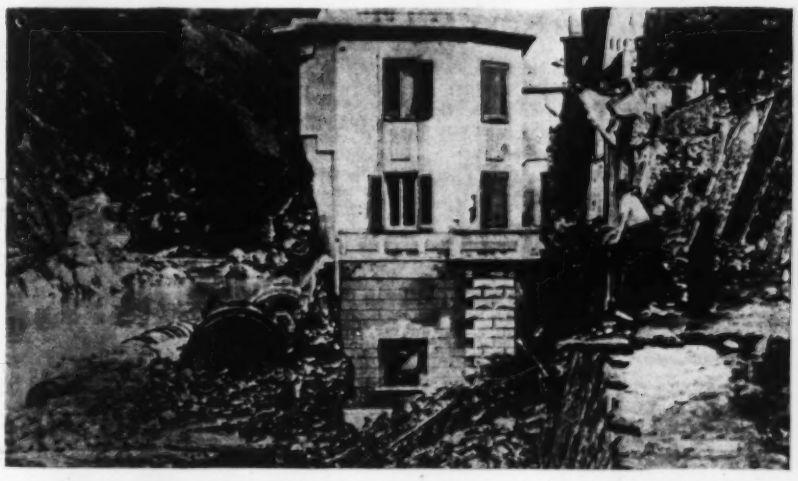
Washington, August 27, 1935.

Civil Service Examination For Junior Engineer

Applications to take an examination for the position of junior engineer must be on file with the office of the U. S. Civil Service Commission, Washington, D. C., not later than September 16, 1935.

Optional subjects are: Aeronautical, agricultural, ceramics, chemical, civil, electrical, mechanical, mining, petroleum, and structural steel and concrete engineering.

The entrance salary is $2,000 a year, less a deduction of 3½ per cent toward a retirement annuity. Applicants must have been graduated with a bachelor's degree in engineering from a college or university of recognized standing upon the completion of a full four-year course. Full information may be obtained from the Civil Service Board of Examiners at the post office or custom house in any city.



Times Wide World

ITALIAN POWER PLANT DESTROYED IN FLOOD

The power plant about 9,000 ft. downstream from Molare Dam on the Orba River in Italy was almost completely destroyed by the waters released when the dam failed on Aug. 13 *(ENR,* Aug. 22, p. 272). This picture, one of the first to reach this country, shows all that remains of the power house which is situated at the point where the river comes out of a narrow gorge (shown at the right center) into a wide point in the river valley. Flanking the power house at the rear is a terraced retaining wall which was breached, apparently by water that came down over the end of the wall. At the lower right is the debris-piled floor of the power house with the two generators exposed, and beyond, lying over the discharge channel, is the penstock line feeding the double-runner turbines in line with the generators but not shown in this picture. No pictures of the dam itself have been received.

Report Holds Florida Canal Injurious to Water Supply

An old report holding that any sea level canal in Florida would seriously threaten the state's fresh water supply was made public on August 26 in a report issued by W. C. Mendenhall, head of the U. S. Geological Survey in a letter to Secretary Ickes.

The report did not discuss the cross Florida canal project now pending under the relief works program, but pointed out that any such project would have a major effect on the fresh water supply in Florida by allowing salt water to come into the fresh water sources. The survey showed that if a canal were constructed at sea level it would have to have a bottom between 30 and 40 ft. below sea level which would mean that in some spots the bed of the canal would be as much as 70 ft. below land level. A canal bed of such depth would cut through the Ocala limestone strata which carries artesian streams to supply the region with drinking water. The danger to be encountered by such an undertaking would be the exhaustion of the fresh water supply and the penetration of salt water into the supply now existing.

The report was cited in a letter from W. C. Mendenhall to Secretary Ickes after some opposition to the building of the proposed canal had been expressed. An allotment of funds for the first year's work on the canal is now before the Advisory Committee on Allotments awaiting recommendation. Original proposals for the building of the canal, which would cost between $99,000,000 and $119,000,000 were turned down by the PWA but later revived when the new relief works fund was appropriated and a plan proposed which calls for the construction of the canal by the army engineers.

Chicago Water Tunnel Blast Kills Two Workmen

Ignition of gas at the base of the new William E. Dever crib on the Chicago Ave. water tunnel, August 26 by a workman using an acetylene torch caused an explosion killing two workmen and badly burning six others. The men were at the top of crib removing construction equipment as all tunnel work had been completed.

Methane gas in small amounts was encountered during construction. The tunnel is now being allowed to fill with seepage through weep holes in the lining and it is presumed that gas entered with this water. Only nominal damage was done to the crib structure.

Canada Aids Elimination Of Grade Crossings

Work of eliminating grade crossings on important railway lines in Canada is being expedited. An annual sum of $200,000 is made available by parliament regularly, but this year the federal government obtained permission to devote $1,000,000 of the special public works allowance to this work. The Minister of Railways and Canals has already announced eight major grade elimination projects, located in different parts of the Dominion, and the Board of Railway Commissioners, under whose jurisdiction such work is initiated, has received applications for 15 further projects, estimated to cost $432,000. The board decides how the work shall be financed; those approved so far have all been on the basis of the federal government paying 70 per cent of the cost, and the local municipality, the province, or the railway concerned having to pay the balance.

Obituary

EDMUND S. STRONG, civil engineer, for 37 years associated with the engineering department, Syracuse, N. Y., until his retirement in 1932 died at his home in that city on August 10.

WENDELL P. MILLER, Columbus, Ohio, contracting engineer, died in Tulsa, Okla., on August 13. At the time of his death Mr. Miller was engaged in work on a municipal project at Tulsa.

PAUL A. IVEY, SR., vice-president in charge of sales of the National Cast Iron Pipe Co., Birmingham, Ala., was killed in an airplane accident near Gilmer, Texas, on August 15.

F. J. CONN, superintendent of bridge construction for the Cincinnati, New Orleans and Texas Pacific, and for the Alabama and Great Southern railroads, of the Southern Railway System, died in Lexington, Ky., on August 9, at the age of 78. Prior to his work with the Southern railroad, Mr. Conn had been associated with the Illinois Central Railroad.

JOHN EBER BLEEKMAN, civil engineer, died at his home in Elmhurst, L. I., on August 24 at the age of 65. Mr. Bleekman had served with railroads for many years. He began with the Wabash and later went with the Santa Fe, later becoming managing director of a syndicate which operated a railroad in South America. He assisted in the building of the Gulf and Florida R.R. and also of the Union Depot in Cincinnati.

LAWRENCE MARSH BARTLETT, 47, of Buffalo, N. Y., died in New York City, August 11. Mr. Bartlett was a graduate of Yale University, and later was for three years an engineer at the Port of Manila, P. I., for the War Department. Later he was in charge of pier construction, Ponce, Porto Rico.

FRANK H. PITCHER, general manager and chief engineer of the Montreal Water and Power Co. up to 1926, when the company was bought over by the city of Montreal, died in that city on August 21 at the age of 64. Since 1926 Mr. Pitcher had lived in retirement.

FRANK E. MERRILL, water commissioner of Somerville, Mass., for about 40 years, and a past president of the New England Water Works Association, died at his home in Dunstable, Mass., on Aug. 24 after a short illness.

CONSTRUCTION STATISTICS OF THE WEEK

ENGINEERING AWARDS total $26,113,000 for the week, above the year's average to date of $25,754,000 but below the three preceding high weeks. This amount is made up of private, $5,595,000 and public, $20,518,000, of which federal is $5,933,000 and state and municipal, $14,585,000. Corresponding figures a year ago were, total, $36,671,000; private, $9,887,000; public, $26,784,000, of which federal was $15,270,000 and state and municipal, $11,514,000.

Private work records a gain this week in commercial buildings at $2,570,000 and in industrial buildings at $1,782,000. Federal work is sharply off. This drops the earthwork, waterways classification to $3,868,000. Highways are down to about half of last week's volume of awards, totaling only $3,128,000 and public buildings awards are down to $3,626,000. Bridges at $2,021,000 are higher and waterworks awards at $5,276,000 are the highest for any week this year.

The larger awards include the U. S. Mint, San Francisco, Calif., $935,000; Extension, U. S. Custom House, Denver, Colo., $643,000; depressed roadway for Queens connection, Tri-borough Bridge, New York, N. Y., $1,579,000; Cajalco Dam, dike and appurtenant works, Metropolitan Water District of Southern Calif., Los Angeles, $4,647,000; earthwork in Second New Orleans Dist., U. S. Engineers, $1,425,000 and $1,106,000; fabricating electric welded steel pipe for Pacific Gas & Electric Co., San Francisco, Calif., $800,000. In Canada, Marine Dept., Ottawa, let dredging in Montreal Harbor, $5,478,000 and the Montreal Harbor Commission awarded Windmill Point Wharf contract at a figure of $1,084,000.

New capital for the week totals $51,716,000 for non-federal work and $39,054,000 for federal work including the percentage of WPA allotments used. State and municipal bond sales total only $1,322,000 for the week and new corporate issues, $2,396,000.

CONTRACTS

(Thousands of Dollars)

	Weekly Average August 1934	Prev. 4 Weeks	Week Aug. 29 1935
Federal Government	$6,382	$14,280	$5,933
State and municipal	11,400	11,849	14,585
Total public	$17,782	$26,129	$20,518
Total private	4,041	6,650	5,595
Week's total	$21,823	$32,779	$26,113
Cumulative to date:			
1934	$940,089,000	1935	$901,373,000

NEW PRODUCTIVE CAPITAL

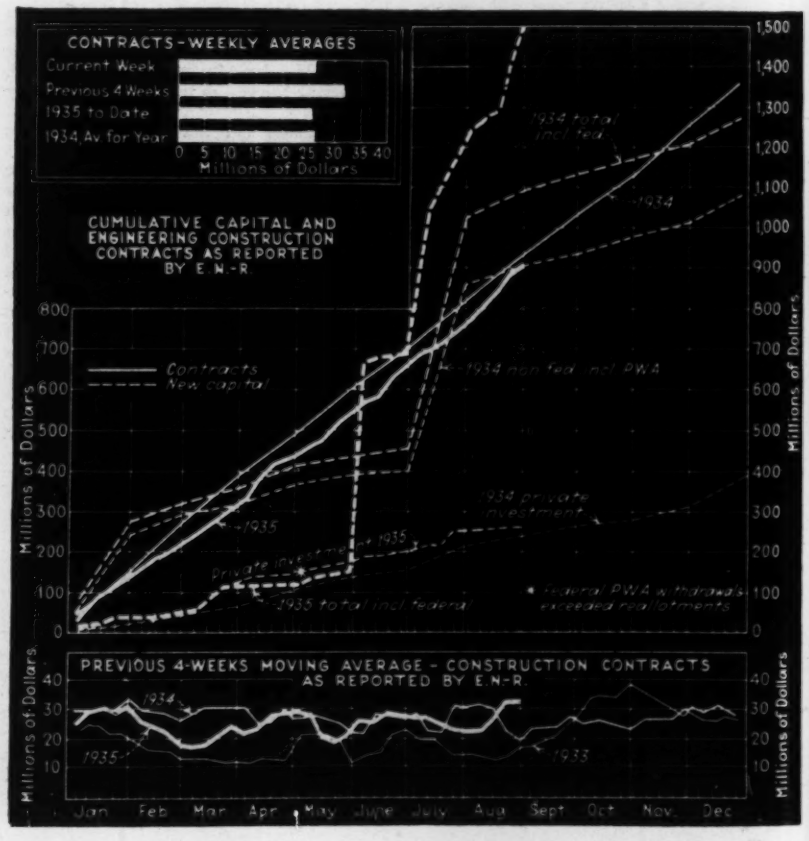
(Thousands of Dollars)

1935	Week Aug. 29	Cumulative
State and municipal	$1,322	$263,467
PWA allotments, S&M	47,219	321,235
RFC loans, S&M	.....	36,084
Corporate issues	2,396	20,520
PWA private	.....	8,629
Local contrib. to WPA	779	4,243
Total non-federal	$51,716	$654,178
PWA federal	39,054	843,614
Total new capital	$90,770	$1,497,792
Cumulative to date:		
1934	$1,090,474,000	1935	$1,497,792,000

Note: These figures include private bonds, and stocks sold for productive purposes; state and municipal bonds for construction; PWA loans and grants to states and municipalities, including the special highway funds; PWA private loans, and allotments for federal construction, deficiency act funds. An arbitrary percentage (25%) of the WPA allotments and local contributions to WPA work is included to allow for the capital additions through the Works Progress Administration division of the new program.

INDEX NUMBER

ENR Cost	1913 = 100	1926 = 100	ENR Volume	1913 = 100	1926 = 100
Aug., 1935	195.10	93.82	July, 1935	96	42
July, 1935	195.18	93.82	June, 1935	122	54
Aug., 1934	198.40	95.37	July, 1934	128	56
1934 (Av.)	198.10	95.23	1934 (Av.)	114	50
1933 (Av.)	170.18	81.80	1933 (Av.)	102	47
1932 (Av.)	156.97	75.45	1932 (Av.)	127	56


CONTRACTS - WEEKLY AVERAGES
Current Week
Previous 4 Weeks
1935 to Date
1934 Av. for Year
0 5 10 15 20 25 30 35 40
Millions of Dollars
CUMULATIVE CAPITAL AND ENGINEERING CONSTRUCTION CONTRACTS AS REPORTED BY E.N.-R.
Contracts
New capital
1934 total incl. fed.
1934
1934 non-fed. incl. PWA
1934 private investment
1935
1935 total incl. federal
* Federal PWA in thereafter exceeds reallotments
Millions of Dollars
PREVIOUS 4-WEEKS MOVING AVERAGE - CONSTRUCTION CONTRACTS AS REPORTED BY E.N.-R.
1934
1935
1933
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.